SAN FRANCISCO WATERFRONT COASTAL FLOOD STUDY, CA

DRAFT APPENDIX A – PLAN FORMULATION

JANUARY 2024

USACE TULSA DISTRICT | THE PORT OF SAN FRANCISCO

Table of Contents

List of Tables

List of Figures

Acronyms and Abbreviations

Acronym	Definition
AEP	Annual Exceedance Probability
ASA(CW)	Assistant Secretary of the Army (Civil Works)
BART	Bay Area Rapid Transit
Bay	San Francisco Bay
BCR	Benefit-Cost Ratio
CCSF	City and County of San Francisco
CE/ICA	Cost Effectiveness/Incremental Cost Analysis
CSD	combined Sewer Discharge
EIS	Environmental Impact Statement
EQ	Environmental Quality
EWN	Engineering with Nature
FEMA	Federal Emergency Management Agency
FWOP	Future Without Project
FWP	Future With Project
FY	Fiscal Year
G2CRM	Generation 2 Coastal Risk Model
GIS	Geographic Information System
GSI	Green Stormwater Infrastructure
HCR	Hazards and Climate Resilience Plan
HTRW	Hazardous, Toxic, and Radioactive Waste
IDC	Interest During Construction
IFR	Integrated Feasibility Report

Acronym	Definition
IMPLAN	Impact Analysis for Planning
IPCC	Intergovernmental Panel on Climate Change
LOD	Line of Defense
LPP	Locally Preferred Plan
MAP	Monitoring and Adaptation Plan
MHRA	Multi-Hazard Risk Assessment
mm/year	millimeter(s) per year
Muni	San Francisco Municipal Railway
NAVD88	North America Vertical Datum of 1988
NED	National Economic Development
NEPA	National Environmental Policy Act
NFS	Non-Federal Sponsor
NNBF	Natural and Nature-Based Feature
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
OMRR&R	Operations, Maintenance, Repair, Rehabilitation and Replacement
OSE	Other Social Effects
P&G	Principles and Guidelines
PDT	Project Delivery Team
PED	Preconstruction Engineering and Design
POA	Period of Analysis
POSF	Port of San Francisco
PV	Present Value

Acronym	Definition
RED	Regional Economic Development
RED	Regional Economic Development
RSLC	Relative Sea Level Change
SFHA	Special Flood Hazard Area
SFMTA	San Francisco Municipal Transportation Agency
SFPUC	San Francisco Public Utilities Commission
SFWCFS	San Francisco Waterfront Coastal Flood Study
SLC	Sea Level Change
SLR	Sea Level Rise
TB	Total Benefits
TNBP	Total Net Benefits Plan
TSP	Tentatively Selected Plan
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WETA	Water Emergency Transportation Authority
WRDA	Water Resources Development Act
WSE	Water Surface Elevation

Section A-1. Introduction

A-1.1 Purpose

This Plan Formulation Appendix documents the project history and the plan formulation strategy to manage the risk of coastal flood damages along the densely populated and economically and culturally diverse portion of the San Francisco Bay (Bay) shoreline of San Francisco, California in a manner which balances the risks to human life and property, while maintaining, enhancing, and restoring ecosystem integrity and coastal biodiversity. The goal of the feasibility study is to identify an economically viable, environmentally acceptable plan that addresses the coastal flood damage reduction needs of the study area and is acceptable to the key federal, state, and local stakeholders.

This appendix documents the evaluations and decisions made to identify a resilience plan for the region to facilitate cost-effective risk reduction actions in response to increasing risk over the period of analysis (POA). It documents the plan formulation strategy and the evaluation of the coastal flood risk management features against traditional U.S. Army Corps of Engineers (USACE) formulation criteria and the U.S. Water Resource Council's 1983 Principles and Guidelines for Water and Related Land Implementation Studies (P&G) that resulted in the identification of the Tentatively Selected Plan (TSP) identified in this draft Integrated Feasibility Report and Environmental Impact Statement (IFR/EIS) and appendices. This Plan Formulation Appendix also previews potential refinements to the TSP that will be considered to improve the timing or alignment of sub-portions of existing measures within study area reaches. Further engineering and economic analysis of the potential refinements will assess whether they improve the plan performance or reduce impacts, and if appropriate, they will be included in the Final IFR/EIS.

The selection of a TSP has been coordinated with the Port of San Francisco (POSF), the non-Federal Sponsor (NFS) and appropriate City and County of San Francisco (CCSF) agencies and has a pending policy waiver with the Office of the Assistant Secretary of the Army (Civil Works) (ASA(CW)) to recommend the plan that maximizes total benefits across all benefit accounts. This appendix describes the plan formulation strategy and screening of plans.

A-1.2 Background

The multiple risk mechanisms along the Bay shoreline of San Francisco, and specifically in the sub-portion of the shoreline that is the study area are described in Section 4.

The study area also includes coastal habitat and environmentally and historically significant areas, such as the Embarcadero Historic District, the Union Iron Works Historic District, and numerous other individual and group resources listed on the National Register of Historic Places. The goal of the feasibility study is to identify an economically viable, environmentally acceptable plan that addresses the coastal flood risk management needs of the Study Area and considers multiple area hazards.

The complexity of the area risks, physical system, and affected stakeholders required a collaborative planning approach to thoroughly assess opportunities and impacts from stakeholders and the public. Since 2018, the NFS has shared planning strategy summaries and study updates to key government partners and stakeholders. Their input was considered in the identification of problems, opportunities, objectives, and constraints.

A-1.3 Project Delivery Team

Plan formulation was accomplished by an interdisciplinary Project Delivery Team (PDT) that included a combination of USACE staff and NFS staff, with technical support from NFS consultants. USACE staff from the USACE Southwestern Division Tulsa District leads the PDT with economics support from the USACE Philadelphia District and engineering with nature support from the USACE San Francisco District.

USACE team members had prior mega-study experience including plan formulation, marine structural engineering, hydrology, hydraulics and coastal engineering, G2CRM flood modeling and economics, engineering with nature, real estate and other required disciplines. The NFS augmented this expertise with experience in shoreline conditions in the study area including seismic risks, familiarity with infrastructure systems, experience with modeling storm conditions in San Francisco Bay and knowledge of local values and priorities.

Section A-2. Planning Framework

The USACE Civil Works planning process follows a standard approach to formulate potential water resource solutions to ensure federal projects comply with applicable laws and guidance. The P&G were developed to guide the formulation and evaluation studies of the major Federal water resources development agencies. ER 1105-2-100 Planning Guidance Notebook and the Planning Manual Part II: Risk-Informed Planning lay out an iterative planning process for all USACE Civil Works studies to develop and evaluate alternative plans (IWR 2017).

A-2.1 Principles and Guidelines Accounts

The P&G established four accounts to facilitate the evaluation and display of the economic benefits and effects of alternative plans. These four accounts are: National Economic Development (NED) Regional Economic Development (RED), Other Social Effects (OSE), and Environmental Quality (EQ). Benefits and effects of all four accounts (P&G 1983) were considered during the plan formulation process, and plan selection emphasized the plan that reasonably maximizes net NED benefits. Per guidance in the memorandum from ASA(CW), dated January 5, 2021, Comprehensive Documentation of Benefits in Decision Document, studies should also identify a plan that reasonably maximizes total net benefits in the NED, EQ, RED, and OSE accounts. The four benefits categories are summarized below.

- NED account: Includes consideration of a measure's potential to meet the planning objective to reduce storm damages, as well as decrease costs of emergency services, lower flood insurance premiums, and consider project costs. Costs and benefits used to fully evaluate the NED objective are not calculated at this stage; however, estimates can be made to gauge the overall cost effectiveness of a measure for this initial screening. Effects of relative sea level change (RSLC) and a measure's adaptability to such change are considered under the NED account.
- RED account: Includes consideration of the potential regional economic impacts of flooding along the San Francisco Waterfront, the Bay Area and the larger California economy. The Institute for Water Resources RED Procedures Handbook (2011-RPT-01) defines RED impacts as regional losses in employment and/or income under the Future Without Project (FWOP) condition. Based on guidance from this handbook, the RED analysis evaluates the regional economic consequences of coastal flooding and sea level rise (SLR) using Federal Emergency Management Agency (FEMA) benefit-cost analysis methodologies.
- OSE account: Includes considerations for the preservation of life, health, and public safety; community cohesion and growth; tax and property values; and the displacement of businesses and public facilities. For evaluation purposes, the OSE account is inclusive of the planning objectives to maintain recreation and safe evacuation routes, and the planning constraint to avoid conflict with legal requirements.
- EQ account: Considers ecosystem restoration, water circulation, noise level changes, public facilities and services, aesthetic values, natural resources, air and water quality, cultural and historic preservation, and other factors covered by the National Environmental Policy Act (NEPA).

The P&G also require that alternative plans are formulated and evaluated in consideration of four criteria: completeness, effectiveness, efficiency, and acceptability.

- Completeness is the extent to which a given alternative plan provides and accounts for all necessary investments or other actions to ensure the realization of the planned effects.
- Effectiveness is the extent to which an alternative plan solves the specific problems and achieves the specified opportunities.
- Efficiency is the extent to which an alternative plan is the most cost-effective means of solving the water resources problems and realizing opportunities consistent with protecting the nation's environment.

- Acceptability is the workability of the alternative plan with respect to acceptance by State, local entities and the public and compatibility with existing laws, regulations, and public policies.

A-2.2 ASA(CW) and USACE Study Guidance

ASA(CW) and USACE policy and study guidance require:

- A plan that maximizes total net benefits (Total Net Benefits Plan [TNBP])
- A plan that maximizes net benefits consistent with the study purpose (NED plan)
- A nonstructural plan, which considers modified floodplain management practices, elevation, relocation, buyout/acquisition, dry flood proofing and wet flood proofing

If requested by the NFS, a Locally Preferred Plan (LPP) may be recommended to include different types or scales of features than the NED or plan that reasonably maximizes total net benefits.

Specific guidance for this study was issued ASA(CW) and USACE on 15 December 2021. This included the following guidance for the formulation process:

- Update Future Without Project Conditions:
    - Update future without project conditions for the study area to account for relative sea level change (RSLC), seismic and frequent (storm, tidal and fluvial) flooding multi-hazard risks.
    - Calibration and independent verification of Coastal H&H modeling will include tidal and storm flooding, with assessments of timing, location, and severity in the study area prior to detailed economic analysis.
    - RSLC scenarios will be incorporated in accordance with USACE policies (ER1100-2-8162, EP1100-2-1).
    - Seismic risks to the existing seawall and other flood risk structures will be characterized.
    - Assess impacts to the regional economy, vulnerable populations, environmental quality, and critical public infrastructure in addition to National Economic Development (NED) impacts.
    - Identify reasonable and prudent actions that would be expected to strategically mitigate extreme storm impacts in advance of the base year.
    - Use of a 100-year period of economic and engineering analysis, due to actions triggered by sea level and flood risk and long-life infrastructure investment.

- Formulation:
    - Develop multi-hazard formulation strategies that reflect timing, location, and severity differences in risk.
    - Distinguish between measures to address seismic risks associated with the flood problem; other alternatives that show them coupled; this facilitates the compare & contrast between the alternatives.
    - Develop at least one stand-alone non-structural alternative.
    - Incorporate engineering with nature, when practicable.
    - Formulate with all 3 USACE RSLC projections, plus additional State of CA projections if a Locally Preferred Plan (LPP) is requested. Formulate measures and alternatives that can be implemented incrementally for varying topography and locations to address varying degrees of risk. Individually and in combination they should describe flexibility in scale and timing of actions (initial and future adaptations) for the desired risk reduction performance as required under Planning Guidance Notebook. The Climate COP concurs with the study approach outlined by the PDT in the RSLC white paper, dated 6 August 2021 as revised on 15 Nov 2021.
- Evaluation:
    - Evaluate and document benefits in accordance with "Comprehensive Documentation of Benefits in Decision Documents" memorandum, dated 5 January 2021.
    - Conduct the benefit analysis using the 3 USACE Sea Level Rise (SLR) curves, with benefit cost analysis based on initial and future adaptations.
    - Use the California Regional SLR curves for the LPP.
    - Evaluate differences in timing of actions and scaling of project features to reflect the pros and cons of adaptability and flexibility of the recommended alternative in regard to realized RSLC.

Section A-3. Planning Horizon and Period of Analysis

The P&G provide the instructions and rules for Federal water resources planning timeframes. One P&G requirement is to evaluate the effects of alternative plans based on a comparison between the most likely future conditions with and without those plans in place. To make this type of comparison, descriptions (often called forecasts) must be developed for two different future conditions: the FWOP condition and the future with project (FWP) condition. The FWOP condition describes what is assumed to be in place if none of the study's alternative plans are implemented and is the same as the "no action" alternative that is required to be considered by the Federal regulations implementing NEPA. The FWP condition describes what is expected to occur as a result of implementing each alternative plan. The differences between the FWOP and

FWP conditions are the effects of an alternative. Measuring these differences across alternative plans enables comparison and, ultimately, plan selection and refinement.

The planning horizon encompasses the study period, implementation period, economic POA, and effective life of the project. The timeframe used when forecasting FWOP and FWP conditions is the POA, or the period over which plan effects are measured (**Figure** A-1**)**.

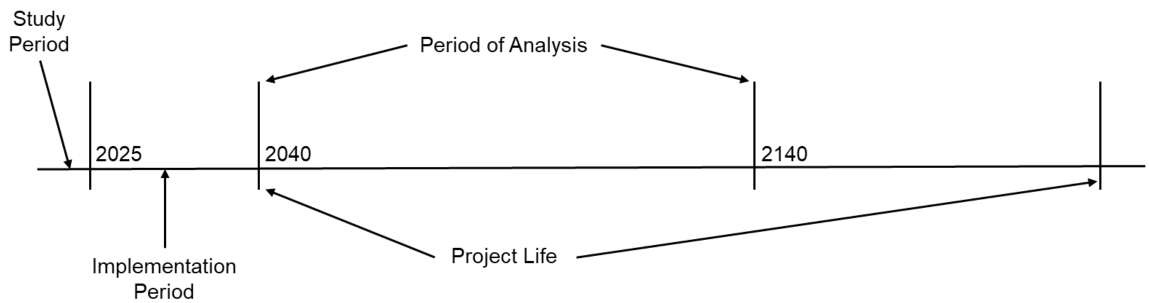


Figure A-1: Planning Horizon

The POA for water resources projects typically extends 50 years following construction. Although project structures will often function for longer than 50 years, forecasting economic and physical conditions and impacts beyond 50 years becomes uncertain, since conditions may change considerably over that length of time. As directed by the USACE guidance for this study, the POA for this study extends 100 years from 2040 until 2140 due to actions triggered by sea level and flood risk and long-life infrastructure investment. For the purposes of analysis, and depending on the alternative, project implementation is expected to begin with refined design beginning in 2025, and construction occurring from 2030 through 2040. The base year is assumed to be 2040, the year the alternative is in place and functioning and benefits are produced. Project performance is quantified by estimating future damages through 2140 for a POA of 100 years. Most alternatives were formulated to include adaptation to the plan alignment or features at the midpoint of the POA (2090) and have a subsequent construction phase. This phasing is detailed more fully in the alternative descriptions, as appropriate.

Alternative plans are proposed with a 2040 first action and a 2090 second action as a planning construct to enable fair comparison of plan effects. Adaptive actions may be taken sooner or later than 2090 depending upon the risk conditions. Future refinements to the TSP will include a more refined implementation and adaptation strategy.

Section A-4. Problems and Opportunities

Problems and opportunities have been identified from technical analyses such as the multi-hazard risk assessment (MHRA) prepared for POSF, and through several other avenues, including coordination with POSF, and extensive consultation with agencies, stakeholders, and the public.

POSF and USACE conducted a series of meetings with regulatory agencies, city and regional agencies, other stakeholders, and the public to gauge key concerns, interests, and preferences around flooding and SLC adaptation along the waterfront, and to identify any potential regulatory implementation challenges. This included meetings with City and resource agency representatives on important resources at risk due to relative sea level change (RSLC), coastal storms, and seismic damages along the waterfront. POSF met with community members along the study area to gather information about coastal storm risk and seismic concerns by region. Community feedback was considered as the PDT identified criteria for screening and evaluation of measures.

A-4.1 Study Area Problems

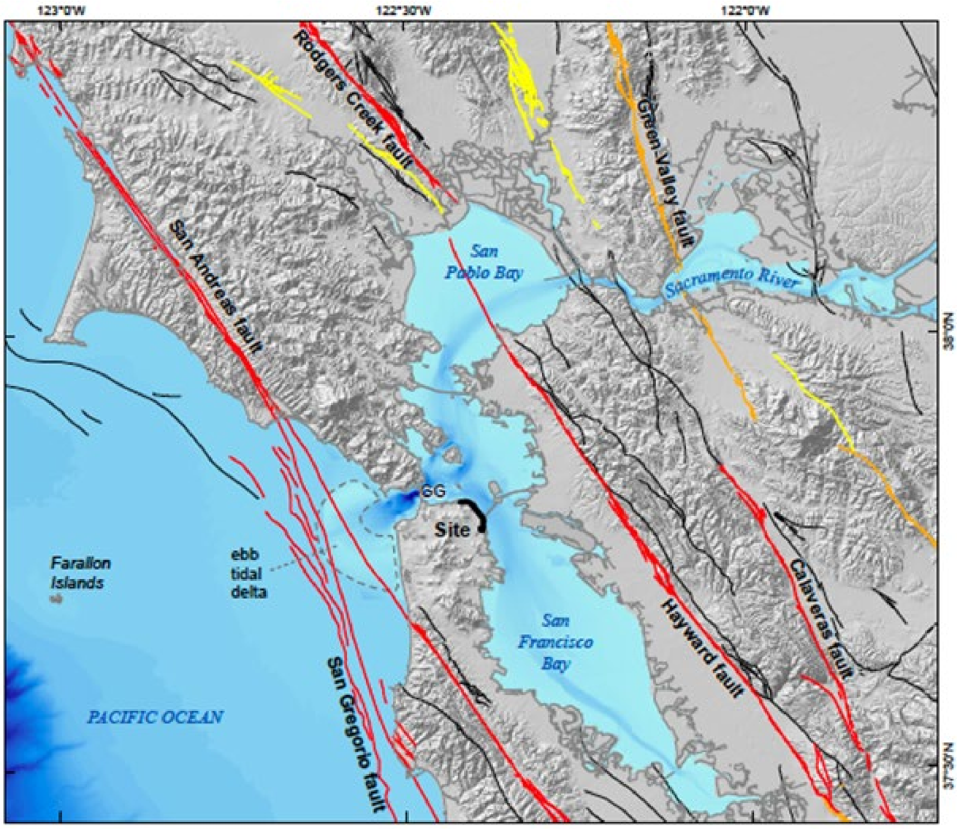
A-4.1.1 Seismic Risk

The Bay Area is a seismically active region. A major earthquake could happen at any time. The 1906 earthquake that shook San Francisco was centered just 3 miles from San Francisco and lasted almost 1 minute, with disastrous impacts. In addition to the immediate damage, the earthquake ignited fires that burned across the city for 3 days, destroying nearly 500 city blocks. The 1989 Loma Prieta earthquake was a much smaller earthquake centered 60 miles away in the Santa Cruz mountains. Loma Prieta shook for only 15 seconds but resulted in over $6 billion of damages across the greater Bay Area and Monterey Bay.

A-4.1.1.1 Earthquake Hazard Overview

There are numerous fault lines crossing the Bay Area, most from northwest to southeast, with the San Andreas and the Hayward faults being the most active and well-known. The POSF's waterfront is located between the two faults (**Figure A-2**). Both the 1906 earthquake (Magnitude 7.9)[1] and 1989 earthquake (6.9) were located along the San Andreas Fault. The Hayward Fault located across the Bay has not experienced a major earthquake since the 1868 Hayward earthquake (6.5). This fault can produce a Magnitude 7.3 earthquake, and because it has not experienced major activity for over 150 years, it is considered the fault most likely to generate a strong earthquake in the near future (USGS 2016). The most recent U.S. Geological Survey (USGS) earthquake forecast for the Bay Area indicates a 72% probability of at least one Magnitude 6.7 or greater earthquake striking the region before 2043 (Working Group California Earthquake Probabilities 2014).

[1] For each increment of 1 on the Richter scale, an earthquake feels 10 times stronger. So, a 7.9 magnitude earthquake is nearly 4 orders of magnitude stronger than a 3.0 earthquake, or 10,000 times stronger.



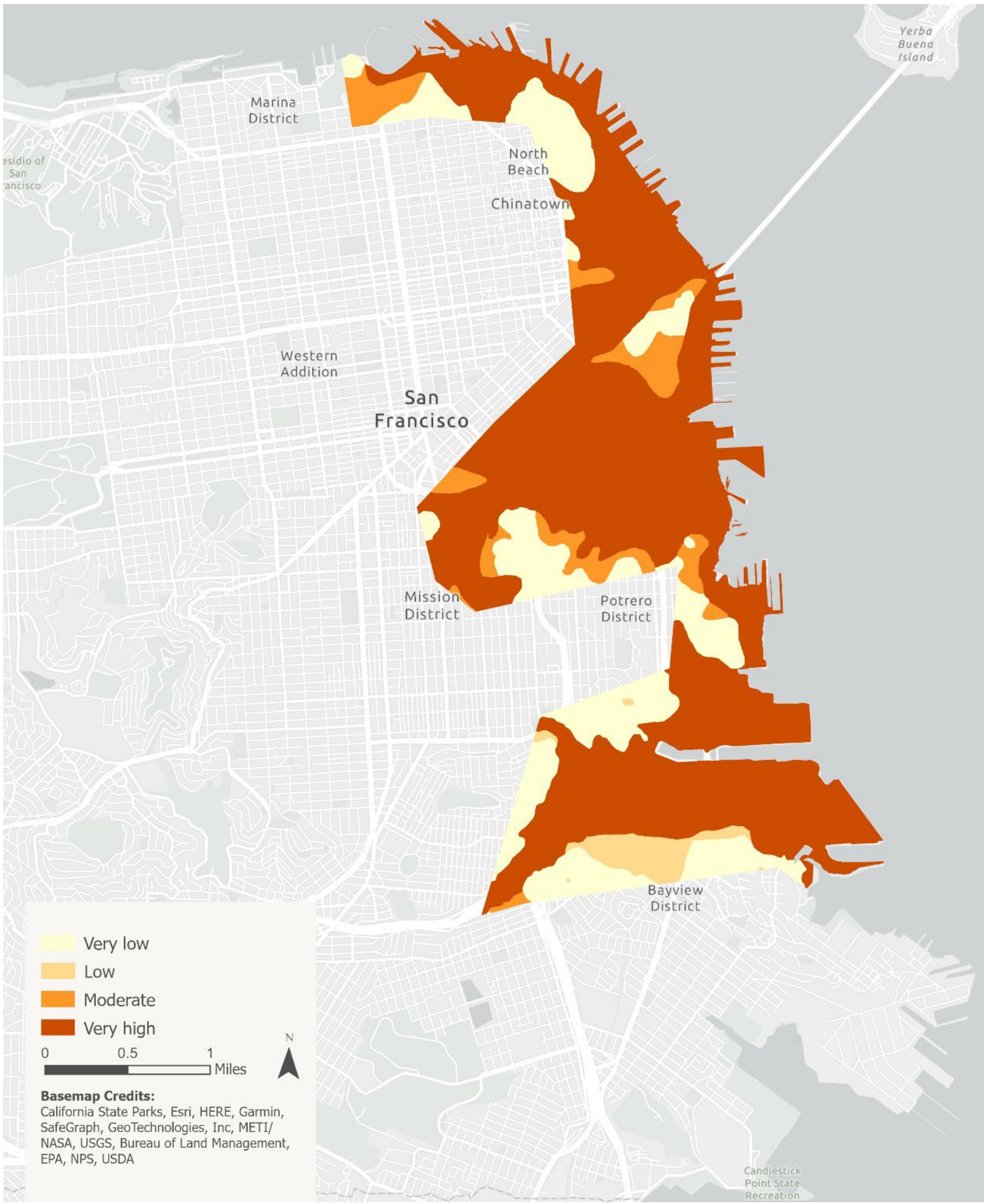
Basemap source: Topographic and bathymetric data from U.S. Geological Survey

Figure A-2: Regional Topography and Faults

Along the waterfront, the ground's earthquake response will vary based on how far below the ground bedrock is located, as well as the type and thickness of the layers of soil and mud, pockets of sand, the presence of Bay fill above the bedrock, and the depth of the groundwater table. There are three main kinds of ways the ground responds to an earthquake: ground shaking, liquefaction, and lateral spreading.

Ground motion/shaking is produced by waves of energy that are generated by a sudden slip on a fault (i.e., fractures in the Earth's crust) or by a sudden release of pressure along the fault that travels through the Earth and along its surface. Ground shaking could affect POSF facilities along the waterfront more than buildings built inland on firmer soil. The POSF's facilities are built on softer ground, such as Bay mud, that can amplify the shaking. For example, along the Embarcadero, this effect is greatest near the Ferry Building where the layer of Bay mud is thick and the bedrock is more than 240 feet below the surface. The ground shaking intensity could be more than double that observed in areas underlain with shallow rock, such as found near Telegraph Hill. Tall and flexible structures, such as the Ferry Building clocktower, may resonate with the soft soil and experience higher levels of shaking than stiff structures (CH2M/Arcadis Team 2020e).

Liquefaction occurs when water-saturated sediment (like sand) temporarily loses strength and acts like a fluid. Strong ground shaking during an earthquake can trigger this effect across large geographic areas. As a result of liquefaction, buildings, roads, and utility lines may lose their foundational support and the likelihood of significant damage increases. The Marina neighborhood in San Francisco experienced significant liquefaction during the 1989 Loma Prieta earthquake and filled areas of the Embarcadero and Mission Bay waterfronts experienced liquefaction in the 1906 Earthquake. **Figure A-3** presents a high-level overview of liquefaction susceptibility for the study area.



Source: (USGS 2006), accessed via MTC/ABAG Hazard Viewer Map (MTC/ABAG 2021)

Figure A-3: Earthquake Liquefaction Susceptibility

This map is based on a study of sediment (specifically Quaternary deposits) types and ages and their susceptibility to liquefaction. More recent studies by POSF and other regional actors have produced a deeper understanding of liquefaction and other earthquake hazard components at specific sites throughout the Flood Study area.

Lateral Spreading occurs when gently sloping or retained slopes experience strength loss and acceleration during an earthquake and the ground moves horizontally and vertically in the downslope or retained direction. This can cause large areas of land to separate from each other, creating cracks in the ground surface, and rapid settlement of the ground as it moves. Lateral spreading poses a significant risk to the Embarcadero Roadway and adjacent Port marine structures and increases the likelihood that buried utilities, such as water, sewer, wastewater, and gas pipelines will rupture. Filled areas of the Embarcadero waterfront experienced lateral spreading in the 1906 Earthquake. **Figure A-4** presents photographs of lateral spreading in San Francisco from the 1906 and 1989 earthquakes.

Source: Left (Givens 1906); Right (O'Rourke et al. 1990)

Left: Lateral Spreading near Lombard Street in San Francisco after the 1906 earthquake.
Right: Differential settlement on the Embarcadero near the intersection with Market Street after the 1989 earthquake

Figure A-4: San Francisco Historic Earthquakes Photographs of Lateral Spreading and Differential Settlement

A-4.1.1.2 Key Findings from Recent Studies

POSF completed a MHRA along the Embarcadero waterfront from Hyde Street Pier to South Beach Harbor to better understand the earthquake risks and how they vary along the oldest stretches of the aging Embarcadero Seawall. Along the Mission Creek/Mission Bay and Islais Creek/Bayview waterfront, earthquake risk findings are drawn from the Initial Southern Waterfront Earthquake Assessment, best available science, and USGS studies (USGS 2014; CGS 2014).

The MHRA was a planning-level study, designed to provide guidance for prioritization of resilience efforts in the Northern Waterfront. The earthquake analysis within the MHRA was limited to POSF facilities (buildings and marine structures under POSF jurisdiction only) and City and regional infrastructure along the Embarcadero, including the roadway, light rail infrastructure and utility infrastructure. The study used a site-specific probabilistic approach to characterize the earthquake shaking hazard at the waterfront. A probabilistic approach considers how all nearby faults contribute to the likelihood of ground shaking at the site, rather than an earthquake scenario approach (e.g., a Magnitude 7.0 earthquake on the Hayward Fault).

The MHRA found that up to 40,000 people could be at risk on POSF property if an earthquake occurs during the day (CH2M/Arcadis Team 2020). The Ferry Building area (Subarea 2-2) and Embarcadero roadway were identified as having particularly high earthquake risk, notably with respect to threatening life safety, disaster response efforts, and day-to-day functions along this waterfront. The POSF- and Embarcadero-related earthquake losses are a near-term problem with over $0.9 billion in losses estimated by 2050 and $1.5 billion estimated by 2100 (CH2M/Arcadis Team 2020).[2]

The Initial Southern Waterfront Earthquake Assessment examined earthquake hazards and potential vulnerabilities from Pier 48 to Heron's Head Park (Subareas 3-2 through 4-5). The assessment was targeted toward specific POSF facilities, including Piers 50, 80, 92, and 94-96. The study found that Pier 50 is expected to exhibit unique seismic behavior than other finger piers due to the presence of solid (filled) ground underneath about 20% of the pier's area. It is a unique and complex structure that serves a key role in disaster response from POSF maintenance. Piers 80 and 94-96 are primarily sand dikes with high liquefaction and lateral spreading risk. Liquefaction and lateral spreading are also expected at Pier 92, with potential damage to landside equipment and buildings. This study estimates the scale of construction funding to fully mitigate seismic risk at Piers 50, 80, and 94-96 to be greater than $100 million.

A-4.1.2 Flood Risk

The Bay is the largest estuary in the western U.S., with a 300-foot-deep Golden Gate inlet that connects the Bay with the Pacific Ocean. The tides, ocean-driven swells, and extreme ocean water levels all enter the Bay through this single inlet. The large expanse of the Bay combined with the complex topography surrounding the Bay can transform storm-driven winds in a multitude of directions depending on the primary driver of the onshore or offshore winds or the track of the large storm system descending on the Bay Area. The water levels and wave heights of the Bay exhibit a high degree of variability driven by many factors, including the bathymetry, astronomical and oceanic cycles (e.g., El Niño Southern Oscillation, Pacific Decadal Oscillation), windspeeds and direction, and atmospheric events such as extratropical cyclones and

[2] These economic estimates include direct damages, disruption, supply chain impacts, and income spending impacts throughout the Bay Area. However, they are limited to economic impacts triggered by damage to POSF buildings and marine structures as well as mobility infrastructure within POSF's jurisdiction. The estimates do not include economic impacts to other buildings and infrastructure throughout the entire Flood Study subareas along the Embarcadero or beyond.

atmospheric rivers. In the Bay, no single storm event produces the highest water level and highest wave hazard along the entire 400-mile shoreline of the Bay.[3]

Coastal flood hazards relevant to the 7.5-mile San Francisco Waterfront study area are organized below into four interrelated categories: coastal flooding, inundation, waves, and erosion.

Coastal flooding occurs when Bay water levels rise above the shoreline along the waterfront, overtopping the shoreline and temporarily flooding inland areas. Most of the developed areas along the shoreline are built on Bay fill, are generally low-lying and flat, and only a few inches to a few feet above the Bay's existing highest annual tides (Port of San Francisco 2020). Because of this, the extent of flooding and the potential damage and disruption that can occur are sensitive to small changes in Bay water level elevation (e.g., ± 6 inches) once the shoreline is overtopped. Coastal flooding already occurs approximately annually along the lowest spots of the shoreline, such as near Pier 14 by the Agriculture Building, where Bay water levels and waves overtop the shoreline and cause disruption of pedestrian and vehicle traffic along the Embarcadero promenade and roadway.

The existing risk of coastal storm damages are currently isolated to low-lying areas along the waterfront where land elevations are less than +10 feet North American Vertical Datum of 1988 (NAVD88), which is the average height of the seawall. The height of the seawall varies, as do heights along the entire waterfront. Specific low points along each reach are as follows: Reach 1 (9.7 feet); Reach 2 (8.1 feet); Reach 3 (6.6 feet); Reach 4 (6.9 feet). An example of past overtopping of the seawall occurred during an extreme tide in November 2015, resulting in Bay waters flooding the Embarcadero promenade along the waterfront near the Ferry Building**)**. This event damaged steel plate joints, shut down at least one lane of traffic along the Embarcadero corridor, and posed a safety hazard to pedestrians. Additionally, in March 2023, a winter storm with high winds, led to extreme wave activity causing substantial shoreline overtopping at low tide (**Figure A-5**).

[3] The Coastal Storms Report (CH2M/Arcadis Team 2023) provides a robust description of the cycles and processes that drive the variations in Bay water levels and waves.

Figure A-5: Overtopping of Seawall in March 2023

Table A-1 presents a range of frequent to extreme water levels for the Presidio tide gauge, located off the San Francisco shoreline near the Golden Gate Bridge, and two locations near the northern and southern ends of the study area. Extreme High Bay water levels (e.g., the 1% annual exceedance probability [AEP] water level) are only about 1 foot above the 10% AEP water level, 2.5 feet above the monthly high tide water levels, and 3.5 feet above mean higher high water.

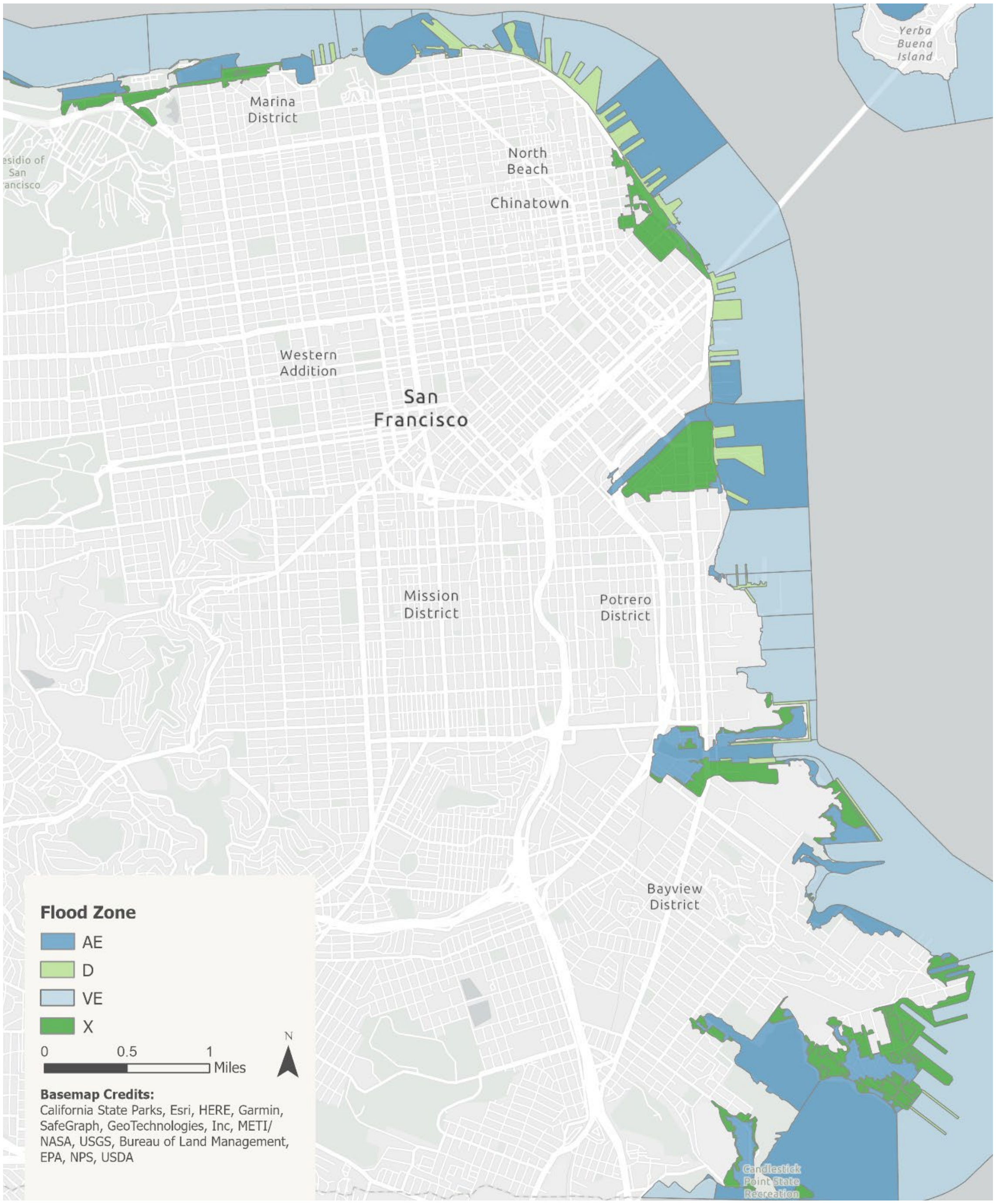
This tight range in water level elevations from frequent to extreme recurrence intervals makes San Francisco very sensitive to SLR**.** With 1 foot of SLR, coastal flood risk increases by a factor of 10. With 3.5 feet of SLR, areas exposed to rare (but foreseeable) coastal flooding will experience flooding with daily high tides.

Table A-1: Existing Water Levels for Frequent to Extreme Recurrence Intervals

AEP	Recurrence	Presidio[a] (feet NAVD88)	Pier 39[b] (feet NAVD88)	Pier 94[c] (feet NAVD88)
99.9994%	1-month	6.89	6.92	7.24
98.17%	3-month	7.07	7.11	7.53
86.47%	6-month	7.24	7.34	7.74
63.21%	1-year	7.44	7.63	8.02
18.13%	5-year	7.99	8.18	8.46
9.52%	10-year	8.09	8.43	8.72
3.92%	25-year	8.36	8.80	9.09
1.98%	50-year	8.57	9.09	9.40
1.00%	100-year	8.78	9.40	9.67

[a] Calculated from Presidio tide gauge data from 1974 – 2003 to match modeled time horizon.
[b] Calculated from 2-dimensional hydrodynamic model output near the northern edge of the study area, offshore of Pier 39.
[c] Calculated from 2-dimensional hydrodynamic model output near the southern edge of the study area, offshore of the Pier 94 wetlands.

Figure A-6 presents the Special Flood Hazard Areas (SFHAs), which are areas at risk of flooding during a 1% AEP water level event according to the FEMA Flood Insurance Rate Maps. In coastal areas, SFHAs are primarily designated as VE or AE zones with an associated flood inundation elevation, and the two zones are distinguished by wave height. VE and AE zones represent areas where wave heights are greater than 3 feet and less than 3 feet, respectively. While VE zones are designated due to the potential for significant wave damage, FEMA guidance recommends consideration of wave heights as low as 1.5 feet as posing significant risks to structures when constructed without consideration of coastal hazards. Much of the port's shoreline is mapped as Zone D, which indicates possible but undetermined flood risks.



Source: (FEMA 2021; SF Planning 2021)

Zones AE and VE are within the SFHA and are subject to 1 or more feet of flooding during the 1% annual chance event. Zone D includes waterfront piers, which is an area of possible but undefined flood risk. Zone X-Shaded are subject to inundation during a 0.2% annual chance flood or inundation of less than 1 foot depth during a 1% annual chance flood. Unshaded areas are also considered Zone X and are areas of minimal flood risk or areas which FEMA did not study.

Figure A-6: San Francisco FEMA Flood Insurance Rate Map

Coastal inundation refers to the permanent inundation of land by high tides, such as areas that are below mean higher high water. Under existing conditions, only the wetland areas, including fringe wetland areas along Islais Creek and Mission Creek are inundated on a regular basis. However, as sea levels rise, the area inundated by the high tides will increase.

Waves in the Bay include both longer period ocean-driven swell propagating through the Golden Gate, and locally generated, wind-driven waves. Ocean-driven swell waves propagate parallel to the northern San Francisco shoreline and may pose a hazard to the Aquatic Park municipal pier and the port's finger piers. Although these waves temporarily increase Bay water levels, they are not a significant direct wave hazard along the shoreline.

Wind-driven waves within the Bay are the dominant wave hazard. The wind climate above the Bay and the larger Bay Area is highly variable, and the steep topography, hills, and valleys throughout the Bay Area drive complex local wind patterns. Due to the large size of the Bay, the winds have sufficient fetch to generate wind-driven waves that are 3 to 5 feet high along the most exposed sections of the Bay shoreline when windspeeds are high and the wind is blowing toward the shoreline. Strong windspeeds in almost any direction will impact a section of the Bay shoreline.

Understanding waves and local wave conditions is a crucial part of coastal flooding risk management along the shoreline, both with respect to infrastructure design (including coastal defense structures) and understanding residual risk. Waves are essentially energy passing through a fluid (in this case, water). They can be measured and experienced as wave runup; as splashing and overtopping; as a dynamic force on piers, wharves, and other coastal structures; and as waves that propagate inland once a shoreline is overtopped.

- ***Wave runup*** is the culmination of the wave breaking process as waves approach sloped or vertical shorelines. Wave runup includes both wave setup (the mean increase in water level as waves get slower and increase in height near the shoreline) and swash (the decelerating water that surges up the shoreline during and after the wave breaks). The slope and roughness (e.g., smooth, cobbled rock, vegetated) of the natural shoreline or engineered structures are key parameters in defining how high the waves can runup the shoreline. Smooth vertical walls have the highest potential wave runup elevations, whereas a slopped shoreline with riprap armoring will dissipate wave energy and reduce the wave runup potential.

- ***Wave overtopping*** occurs when the wave runup elevation exceeds the height of the shoreline (e.g., the top of a levee or floodwall) potentially flooding inland areas. Overtopping can range from a spray to a splash to a stream of water, depending on shoreline, Bay water level, and wave characteristics. Waves overtop low spots along the shoreline under existing conditions. Marginal wharves along parts of the San Francisco shoreline act as a barrier, blocking waves from overtopping the adjacent bulkhead wall.

- ***Overland wave propagation*** occurs along natural, gently sloped shorelines when water levels are high enough to allow waves to travel inland across the shoreline as opposed to breaking and running up the face of a more sloped or vertical structure. Under existing conditions, overland wave propagation only occurs in small areas where the shoreline is not hardened, for example, along the Pier 94 wetlands and portions of Heron's Head Park. As waves propagate inland over wetlands and vegetated areas, they generally decrease in height due to wave energy dissipation. However, waves that propagate over inundated areas with sufficient water depth and limited obstructions (e.g., parking lots) may increase in height.
- ***Waves*** are also a powerful and *dynamic force* that can cause significant structural damage. Along the shoreline, waves crash into the piers and wharves causing them to shake and vibrate. This contributes to wear and tear on the structures. Waves can cause damage gradually over time, and they can cause abrupt damage during an extreme storm event. The degree of damage depends on the storm conditions, the direction of the waves, and a structure's condition.

Coastal erosion occurs when currents and waves wear down and carry away earthen or engineered materials along the shoreline. In areas with a natural or naturalized shoreline, like the Pier 94 Wetlands or Heron's Head Park, erosion can lead to inland migration of the shoreline. For engineered coastal defenses (e.g., a floodwall or seawall), erosion is of particular concern at the toe of the structure because erosion can weaken the foundation of the structure and increase the risk of failure.

Groundwater shoaling occurs when a water table gains elevation and becomes shallower from the land surface. **Groundwater emergence** occurs when the water table intersects the land surface, resulting in either the formation of a new spring, seep, ponding, or evaporative deposit, depending on the nearby climate and topography. With sea level rise, the water table at the shoreline will rise to meet the new sea level. This is because the lowest elevation of the coastal water table is likely on average near or above mean sea level in most coastal areas, unless losses other than discharge to the coast reverse flow such that saline water flows inland and causes intrusion (e.g., pumping or evaporation). Shallow and emergent groundwater represent hazards for surficial flooding, water quality, transportation, and shallow buried infrastructure. Understanding the characteristics of groundwater and influence that relative sea level change and the 6-foot tidal range will have on the existing condition is important to ensuring coastal flood risk reduction solutions do not exacerbate flood risk from another source.

A-4.1.2.1 Sea Level Change and Flood Risk

SLR serves as a risk multiplier for all coastal hazards. SLR can also impact shallow groundwater tables, and it has implications for stormwater and wastewater management and interior drainage. This section presents a summary of information about RSLC observations and projections, as well as the influence of RSLC on coastal flood risks related to extreme water levels, high tides, and shallow groundwater. Further information is documented in *Appendix B: Engineering* and *Appendix J: Climate*.

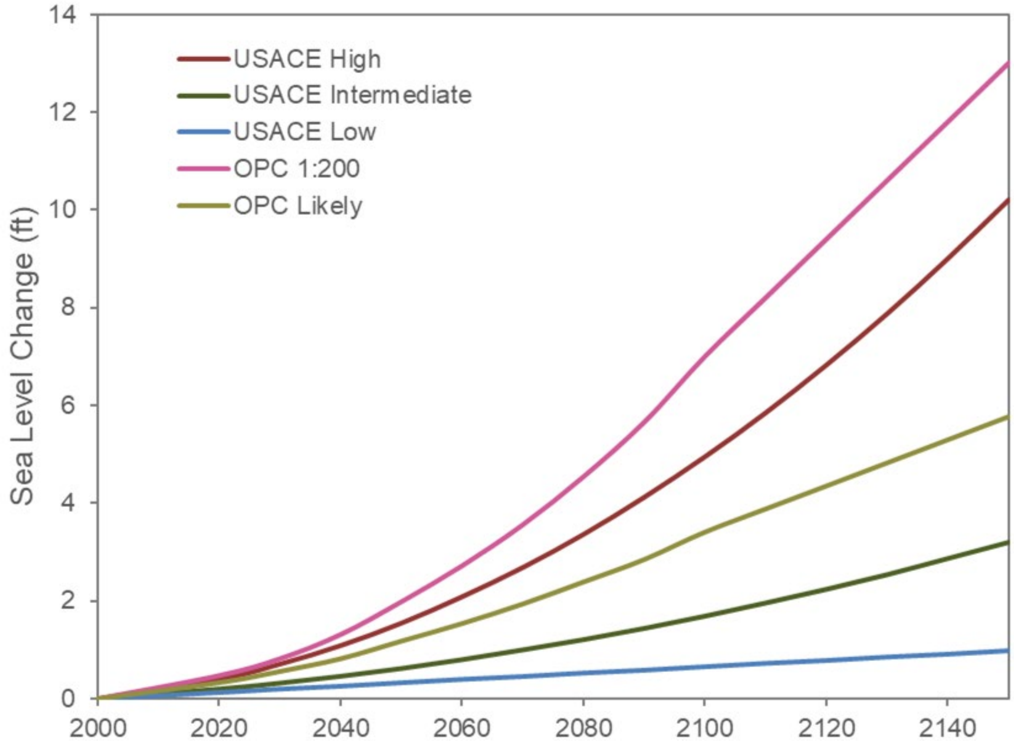
A-4.1.2.1.1 Sea Level Change Record and Projections

The National Oceanic and Atmospheric Administration (NOAA) San Francisco Presidio tide gauge was selected to formulate the RSLC strategy based on its proximity to the study area. The observed SLR trend for the gauge from 1897 to 2020 is 1.97 millimeters per year (mm/year) with a 95% confidence interval of ± 0.17 mm/year (Sweet 2022).

The project delivery team (PDT) formulated alternatives considering five RSLC curves (**Figure A-7**) to address the Federal USACE requirements, as well as the requirements of the State of California and CCSF (Port of San Francisco 2020; CPC 2020). The three USACE RSLC curves are based on science presented in the National Research Council's (NRC) 2012 report, using best available science at the time of publication, including local tide gauge and other information to develop regional projections based on the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment (IPCC 2007; NRC 2012; USACE 2019).The three USACE curves were derived from the USACE SLC Calculator using the guidance provided in ER 1100-2-8162 (USACE 2019, 2020).

The State of California curves reflect the Likely projection and 1-in-200 projection for San Francisco (OPC and CNRA 2018). Currently, the California SLC projections are based on NOAA's 2017 report (Sweet 2017), which relies on the IPCC Fifth Assessment (IPCC 2014). The State of California is in the process of updating its recommendations based on the 2022 Federal Interagency Sea Level Rise Report (Sweet. 2022), which relies on the IPCC Sixth Assessment (IPCC 2021).

IPCC revised the approach for estimating potential climate change between the Fourth, Fifth, and Sixth Assessments. No simple comparison is available to translate the previous NRC (2012) scenarios used to compute the USACE RSLCs to the IPCC (2014) or IPCC (2021) scenarios that form the basis of the State of California's recommendations. However, collectively, the three USACE SLC curves and two California SLC curves are similar to the SLC scenarios recently updated by the Federal Interagency Sea Level Rise Task Force (Sweet 2022).



This figure displays both California Ocean Protection Council and USACE RSLC Curves baselined to the year 2000 for the purposes of illustration. Inputs for analysis were developed in accordance with USACE requirements, detailed in the Coastal Storms Report within Appendix B.

Figure A-7: USACE and the State of California Sea Level Rise Scenarios

Table A-2 shows the increase in sea level (in feet) under various projections for the time horizons evaluated. The table is organized from most conservative (swift) to least conservative (slow) SLR projections. For example, the State of California 1-in-200 projection predicts 1.4 feet of SLR by 2040, whereas the USACE Low projection predicts that 1.4 feet of SLR may not occur until later in the next century, after the 100-year POA.

Table A-2: Increase in Sea Level (in feet) Across Time Horizons and SLC Curves

Time Period	State of CA 1-in-200	USACE High	State of CA Likely	USACE Intermediate	USACE Low
2040	1.4	**1.1**	0.8	**0.5**	**0.3**
2065	3.3	**2.4**	1.8	**0.9**	**0.4**
2090	5.8	**4.1**	2.9	**1.4**	**0.6**
2115	8.6	**6.3**	4.1	**2.1**	**0.8**
2140	11.7	**9.0**	5.3	**2.9**	**0.9**

Note: Cell color scheme identifies similar SLR increments. Darker colors indicate greater increases in sea level.

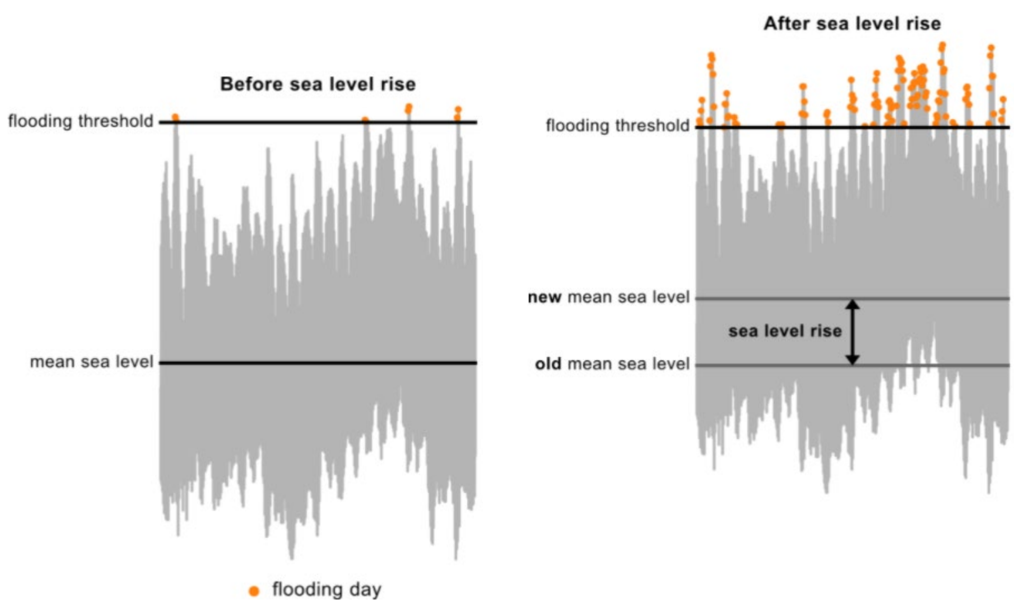
A-4.1.2.1.2 Influence of Sea Level Change on Extreme and Tidal Water Levels

Most analyses of flooding, and flood-related damage and loss, focus on extreme events with relatively rare occurrence frequencies, such as the 1% AEP water level. The San Francisco waterfront required analysis of increasing flood risks due to more frequent events, given the characteristics of this study area and the RSLC rates considered. In the Bay, the difference between mean higher high water and the 1% AEP water level is on the same order of magnitude as future SLR by the year 2100.

Future flooding by lower magnitude, high-frequency events could result in more damage and disruption to shoreline communities and infrastructure than higher magnitude, lower frequency events (Sweet 2017; Ghanbari et al. 2019; Taherkhani et al. 2020). High-frequency events include very frequent events (such as the 6-month to 1-month water level), and near daily events or high tide flooding.

For example, if sea level rises by 6 inches, a 1% AEP water level will become about a 4% AEP water level in the Bay (Vandever et al. 2017; CCSF 2020). If sea levels rise by 24 inches, Bay Area coastal communities could experience multiple flood events, in addition to 90 to 150 days of high tide flooding, each year (Ghanbari et al. 2019; Sidder 2019). **Figure A-8** provides a schematic example of this dynamic. Before SLR, a hypothetical flooding threshold could be overtopped a few times each year, primarily in the winter season (**Figure A-8, left**). With SLR, the same flooding thresholds could be overtopped frequently throughout the entire year **(Figure A-8, right**). This more frequent flooding will cause chronic and cumulative damages (FEMA 2015; Sievanen et al. 2018; Sidder 2019), and ultimately the frequent flooding will transition to permanent inundation by regular high tides.

Figure A-9 presents high tide (monthly) inundation and extreme (1% AEP) water level flood extents under the USACE intermediate and USACE high SLR projections.



Source: (University of Hawaii 2021)

Figure A-8: Schematic of the Effect of Sea Level Rise on Flooding Events

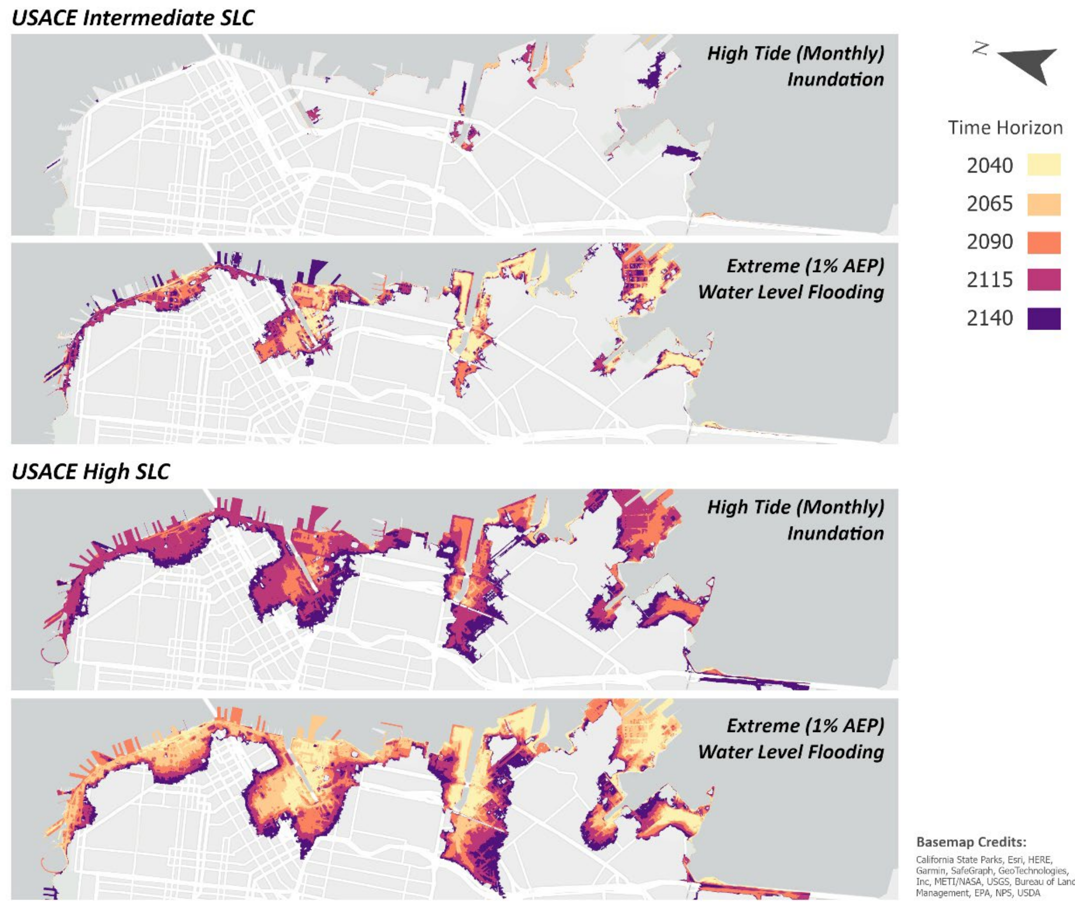


Figure A-9: High Tide (monthly) Inundation and Extreme (1% AEP) Water Level Flooding with USACE Intermediate and USACE High SLC

A-4.1.2.2 Combined Sewer System

High coastal water levels impact the city's combined sewer system. Potential impacts of high coastal waters in the Bay Area (with or without coincident rain events) include overtopping seawalls, water backing up into storm drains, ponding, delays in stormwater drainage to receiving bodies, surface flooding, pressurization of storm drains, damage to underground pipes, and sinkholes. CCSF's impact assessment states that discharge capacity of outfalls will be reduced under rising sea level scenarios (CCSF 2020). The PDT will work with the local infrastructure owner to quantitatively or semi-quantitatively evaluate the FWOP overland flood flows.

As sea level rises, the ability for the system to discharge to the Bay and creek by gravity will be hampered by the hydraulic gradient. Climate change effects and altered sea levels will affect the operation and viability of the current system and these operational issues will be expected in the absence of a Federal project or other corrective action. If corrective actions are coordinated with the Federal project, local and other Federal cost savings are expected to result from the collaborative problem solving and effective deployment of capital.

A-4.1.2.3 Transportation and Critical Infrastructure

Nuisance flooding impacts and major storms pose flood risk to the San Francisco Municipal Railway (Muni) and Bay Area Rapid Transit (BART) underground transit systems and to core transportation corridors such as the Embarcadero and Third Street transit corridor. As sea levels continue to rise, flooding frequency, magnitude, and duration will likely increase, which exacerbates risk to the BART Transbay Tube, Muni light rail, key utility infrastructure, Water Emergency Transportation Authority (WETA) and Golden Gate Ferry service, and waterfront businesses and neighborhoods that depend on the seawall. If flooded, base assumptions of flood risks include:

- Electrical, mechanical and communications equipment will need full replacement once flooded due to complete failure or decreased service life
- Time required to return the system to limited operations (25% normal capacity), which is dependent upon full pump out of flood waters, cleanup of debris, and minor repairs to allow limited operations
- Full operations timeframe (weeks/months) to return full operations (100% normal capacity), replacing all damaged equipment to mitigate future reliability issues
- Prior studies are being used to estimate economic losses for BART/Muni transit delays associated with coastal flood risk and SLC
- WETA and Golden Gate Ferry service is expected to lose ridership and revenue due to system disruption caused by flood damage at ferry terminals. Revenue losses are estimated using disruption time estimates from Hazus and assumptions of the ability to berth elsewhere along the waterfront.

A-4.1.2.4 Shallow Groundwater Response to Sea Level Change

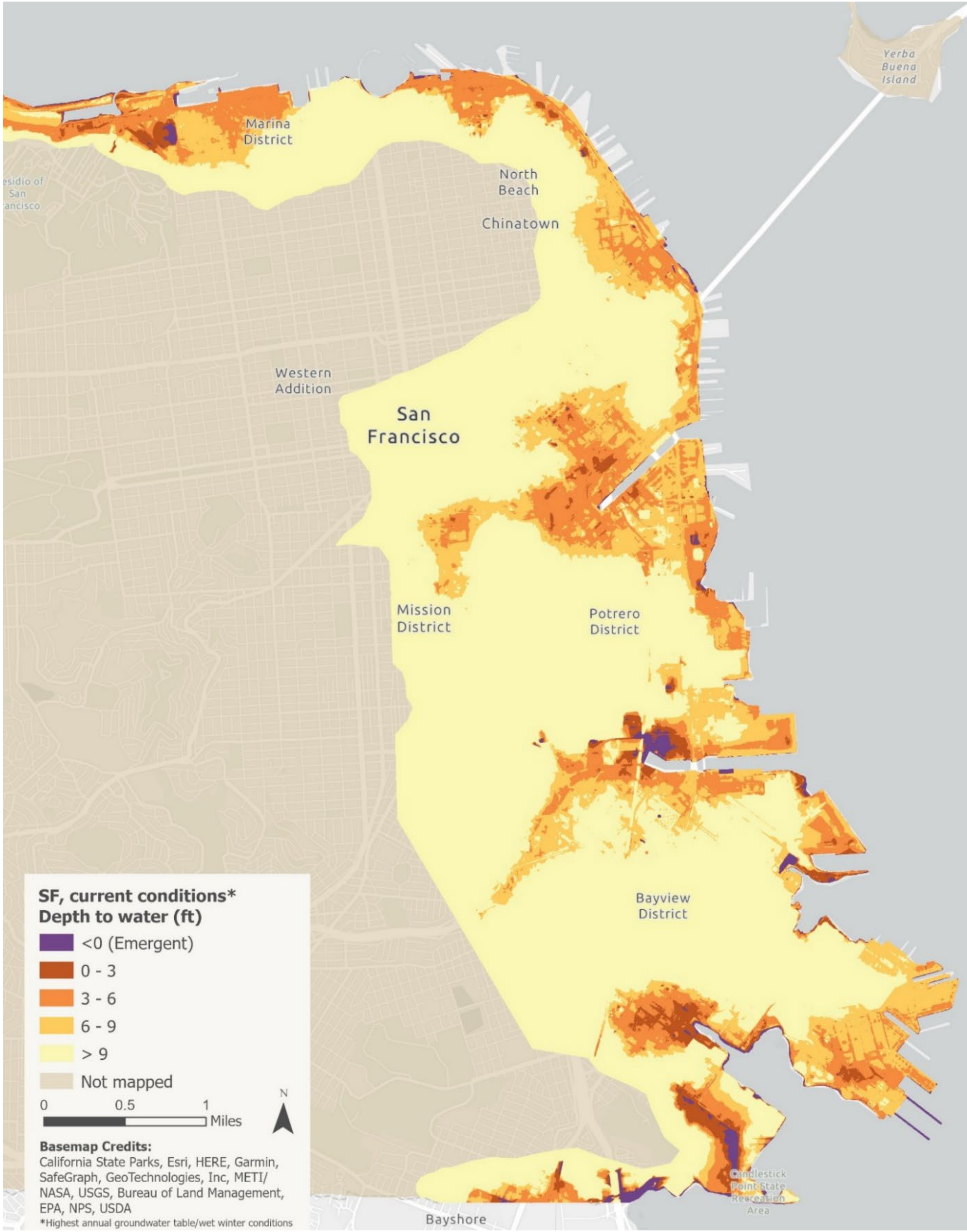
As described in a recent study by May et al. (2022), the response of shallow groundwater to SLR is a relatively new field of study. In nearshore coastal areas like San Francisco, where shallow aquifers are unconfined, the groundwater table will rise as sea levels rise. This threat can flood communities from below, damaging buried infrastructure and roadway subgrades, increasing infiltration into sewer systems, flooding below grade structures, mobilizing contaminants, and emerging aboveground as an urban flood hazard, even before coastal floodwaters overtop the shoreline. Several studies have identified various locations where emergent groundwater is happening today and is projected in the Bay Area (Plane, Hill, and May 2019; Christine May 2020; CL May et al. 2022).

Groundwater rise will contribute to inland flooding in low-lying coastal communities, with impacts often occurring earlier, and farther inland, than coastal flooding from overtopping of the Bay shoreline (Befus et al. 2020; Bosserelle, Morgan, and Hughes 2022; Plane, Hill, and May 2019; Rahimi et al. 2020). Rising groundwater has the potential to impact coastal communities long before the groundwater rises aboveground and creates a new flood hazard (Christine May et al. 2020; Michael et al. 2017; Plane, Hill, and May 2019; Rotzoll and Fletcher 2013). The significance of rising groundwater and groundwater inundation may create the need to re-evaluate SLR driven flooding in some communities to develop effective flood risk reduction strategies (Habel et al. 2020). Failing to account for groundwater rise on the landward side of flood risk reduction structures (e.g., levees and seawalls) could result in maladaptation if the community continues to flood from below.

Figure A-10 shows the existing depth to groundwater mapping for San Francisco, including the Flood Study area, representing the highest annual groundwater table during a wet winter. The groundwater table is within 6 feet of the ground surface across most of the shoreline and nearby low-lying areas. Most underground infrastructure is located within 6 feet of the ground surface, and while underground infrastructure has been designed to account for the historical highest annual groundwater table, it may not have been designed to account for increases in the groundwater table.

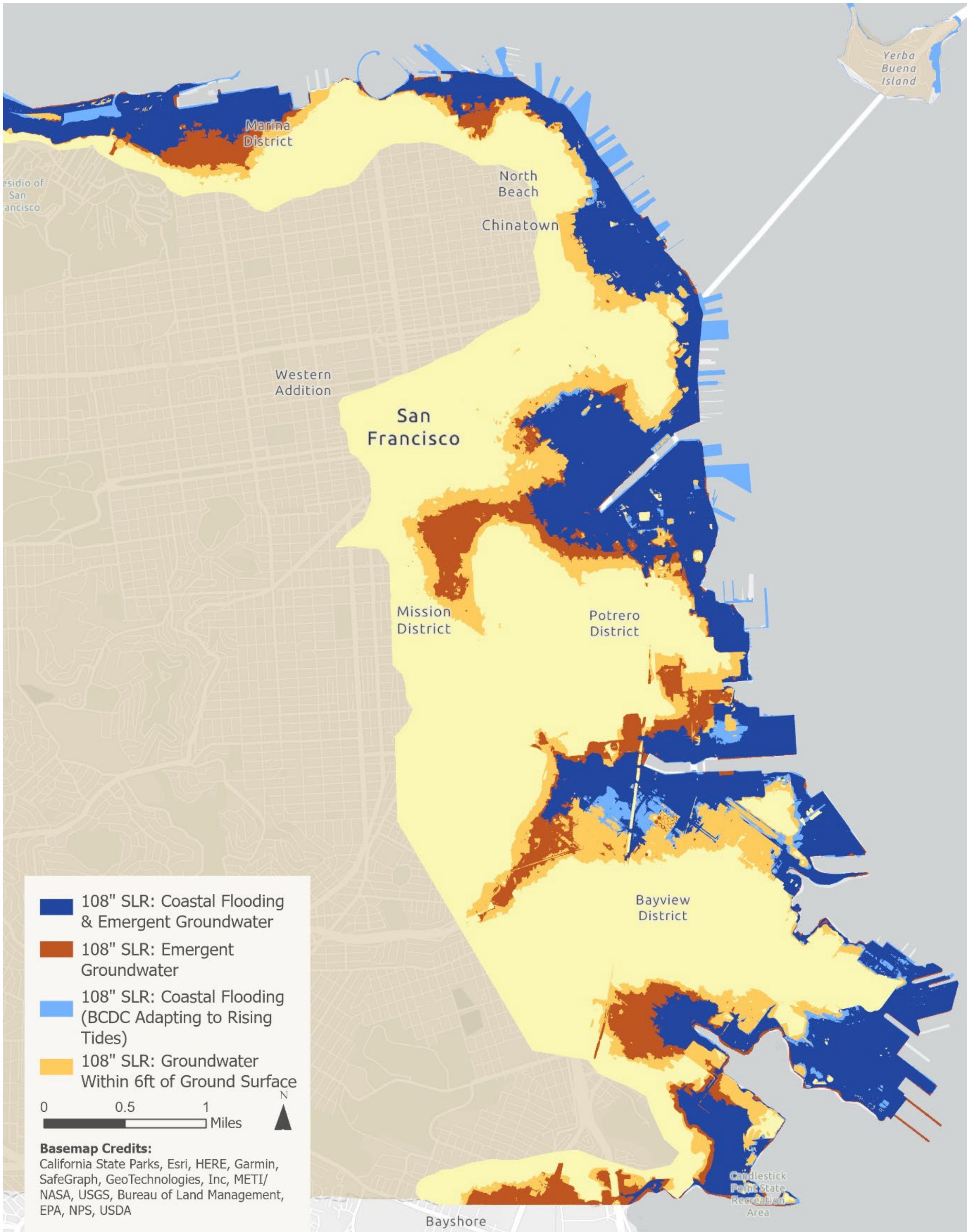
Figure A-11 highlights an area along the northern Islais Creek shoreline with the potential for emergent groundwater under existing conditions. This area floods regularly during rainfall events, with more severe flooding observed when Bay water levels are high.

The same study by May et al. (2022) approximated the future groundwater conditions across 10 SLC scenarios: 12, 24, 36, 48, 52, 66, 77, 84, 96, and 108 inches. These scenarios align with, and are presented alongside, the SLR scenarios used in the ART Bay Shoreline Flood Explorer (BCDC 2023) and San Francisco's Sea Level Rise Vulnerability and Consequences Assessment (CCSF 2020). In San Francisco, as sea levels rise, the extent of emergent groundwater could increase, with emergent groundwater found further and further inland. This could impact essential services, critical infrastructure, and reduce access to and from several locations within the city and region.



Source: (CL May et al. 2022)

Figure A-10: Depth to Groundwater in San Francisco, Current Conditions



Source: (Pathways and SFEI 2022)

Figure A-11: Future Groundwater Conditions, 108 Inches of Sea Level Rise Scenario

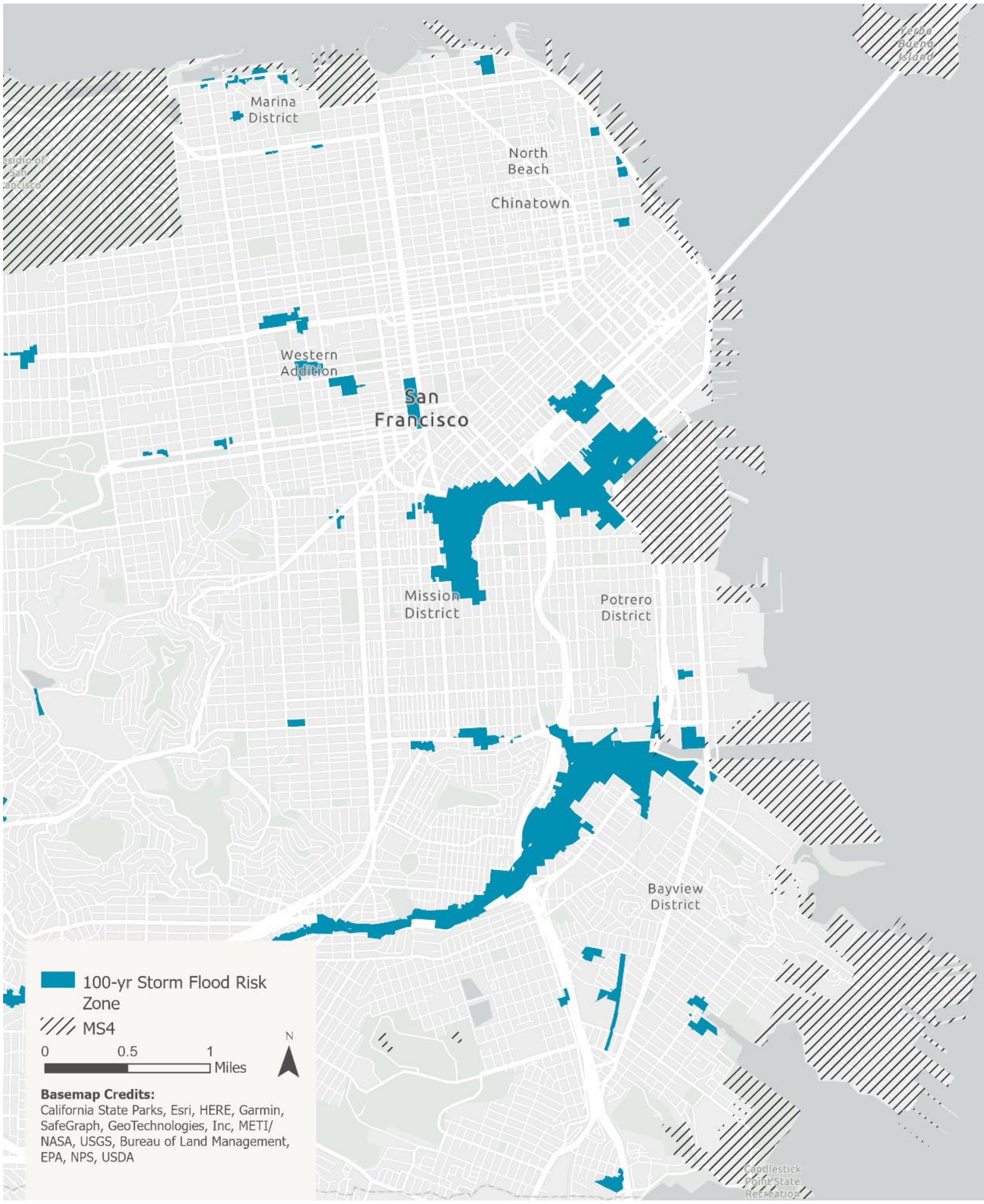
A-4.1.2.5 Inland Drainage

San Francisco operates a combined sewer system that collects and treats both sanitary and stormwater flows in the same network of conveyance structures, including pipelines, storage structures, pumps, treatment plants, gravity outfalls, and pumped outfalls. As noted earlier, the level of service goal for the collection system is to manage flows resulting from the city's 5-year, 3-hour rainfall event, which has a total depth of 1.3 inches over a duration of 3 hours and a peak intensity of 3.13 inches per hour. Some areas along the shoreline are served by separate stormwater pipes. The sanitary flows and some stormwater generated in these areas flow to the City’s Southeast Wastewater Pollution Control Plant, but much of the stormwater flows are either discharged directly to the Bay or captured and treated by green infrastructure facilities. These areas include the POSF’s piers and much of Mission Bay, as shown by the hatched areas on **Figure A-12**. **Figure A-12** presents a map of deep (greater than 6 inches) and contiguous flooding within the area served by the combined sewer system in the event of a 1% AEP rainfall event (100-year, 3-hour).

In a future without a Federal project, modeled results[4] show projected SLR could increase shoreline overtopping over time, which may enter the combined sewer system through catch basins in flooded areas and over combined sewer discharge (CSD) structure weirs.

Alongside SLR, changes in the Bay Area’s storm rainfall intensity could push more stormwater through the CSD outfalls and the city may experience more surface flooding. With greater increases in SLR and rainfall intensities, model data predicts that SLR could counter the increase in rainfall intensity and surface flooding, and the CSD discharge volume could decrease. Eventually, it is possible that the CSD outfalls would no longer discharge flow by gravity into the Bay in the level of service storm.

[4] The study is intended as a planning level tool to illustrate the potential for inundation and coastal flooding under a variety of future sea level rise and storm surge scenarios. The results depict possible future inundation that could occur if nothing is done to adapt or prepare for sea level rise over the next century. The study was performed using a hydrologic and hydraulic computer model, using a digital elevation model created from 2010 LiDAR data and information on existing City-owned infrastructure. The model’s calculations take into account projected sea level rise and storm surge causing elevated bay levels. Model outputs do not account for all the complex and dynamic San Francisco Bay processes or future conditions such as erosion, subsidence, shoreline protection upgrades, or other changes to San Francisco Bay or the region that may occur in response to sea level rise. The model outputs do not account for future conditions such as new construction, City infrastructure upgrades, or other changes that may affect flooding. Although care was taken to capture relevant topographic features and structures in the City, site specific conditions such as property-line solid walls and fences may not be accounted for. Rainfall intensity was increased by applying a percent increase to the existing Intensity-Duration-Frequency curve.



Source: (SFPUC 2022)

This map presents "deep and contiguous flooding", defined as 6-inches deep across an area at least the size of half an average city block. This map may underestimate flooding because it does not reflect inundation in areas served by a separated sewer pipes (areas listed as MS4 in the map).

Figure A-12: SFPUC 1% Annual Chance Precipitation Flood Risk Map

A-4.1.3 Assumed Coastal Resilience Actions

A-4.1.3.1 Seawall

The long-term seawall rehabilitation program includes the incorporation of limited coastal flood risk management measures independent of this study. However, any actions are considered to be limited in scope and scale for the FWOP, and only implemented in areas that are at high risk of failure or will have sustained damage due a future coastal storm or seismic event. Available funding for such repairs is limited. Assumptions are as follows:

- POSF will make improvements along portions of the waterfront, but ground surface elevations are not expected to change.
- The first phase of the Waterfront Resilience Program will address the most critical life-safety upgrades to the Seawall and is estimated to cost $500 million. The proposed Seawall Earthquake Safety and Disaster Prevention Program Bond (Seawall Bond) will fund the majority of this work and leverage other funding sources including state, federal, and private funds.
- Possible improvements include strengthening the ground below and landside of the Seawall, constructing new Seawall segments along limited extents of the waterfront, strengthening, or replacing bulkhead walls and wharves along the Embarcadero Promenade, and relocating or replacing critical utilities.

A-4.1.3.2 Hazards and Climate Resilience Plan

This feasibility study is one critical piece of a larger City commitment to resiliency planning and proactive coordination of City agencies to build and maintain vital City and community functions over the next 100 years.

The climate resilience goals of POSF are formalized in the city of San Francisco's Hazards and Climate Resilience Plan (HCR). The HCR was developed to serve as a roadmap to address the impacts of natural hazards and climate change on the assets and people within the city of San Francisco. It identifies the hazards and risks San Francisco faces and proposes multiple strategies to reduce risks and adapt to climate change impacts. https://onesanfrancisco.org/resiliency/overview.

The HCR was adopted as San Francisco's 2020 Hazard Mitigation Plan by the Mayor and Board of Supervisors on June 16, 2020, and approved by FEMA on July 21, 2020. It updated the city's 2014 Hazard Mitigation Plan, which was coordinated with FEMA to encourage proactive risk reduction efforts are implemented to mitigate post-disaster consequences where possible and to increase efficiency of post-disaster response and recovery programs at the federal and local level. The HCR was developed based on the following principles:

- **Equity & Health**: Proactively work to eliminate racial or social disparities in the impacts of all hazards and/or the distribution of resilience benefits.

- **Community Cohesion:** Empower people and partnerships to reduce vulnerability and promote resilience at the building, block, and neighborhood level.
- **Affordability and Economic Viability:** Help residents and business stay and thrive in San Francisco.
- **Climate Mitigation:** Help eliminate the greenhouse gas emissions, which drive climate change and worsen climate-related hazards.
- **Biodiversity & Connection to Nature:** Restore and leverage local ecosystems to help mitigate hazards and support climate adaptation, while ensuring all residents can access green spaces, parks, and natural habitats and experience nature every day.
- **Science-Grounded Innovation:** Closely monitor evolving climate and hazard-related science and modify approaches appropriately to maintain maximum effectiveness.
- **Good Governance:** Provide dependable and actionable information to foster transparency and openness.

These principles are consistently applied across City agency planning and asset management to monitor and address risk from multiple hazards, including seismic and inland and coastal flooding. The 2020 Hazard Mitigation Plan also reflects the proactive efforts of the City of San Francisco to reduce FEMA post-disaster response costs.

A-4.1.3.3 Waterfront Development Projects

This section describes the actions that CCSF, as well as individual public and private property and asset owners, would take to address SLR and coastal flood hazards in the project area in the absence of a federal project. CCSF would be expected to act rationally within the constraints of available funding sources to continue operation of essential services within and outside of the flooded areas. Individual actors (property owners, agencies, business owners, and residents) are expected to dynamically react to the increasing risk of flood damages, thereby repairing damage from infrequent flood events and eventually taking proactive steps to prevent repetitive damage through floodproofing actions. When the frequency of flooding becomes too great, and impact too disruptive to commerce within the urban study area, it is reasonable to assume zones within the floodplain will be abandoned and converted to land uses compatible with frequent inundation.

There are many development projects underway up and down the waterfront on POSF-owned land, as shown on **Figure A-13**. These new projects not only bring new investment to the city, but also will provide more places for people to live, work, shop, and visit.

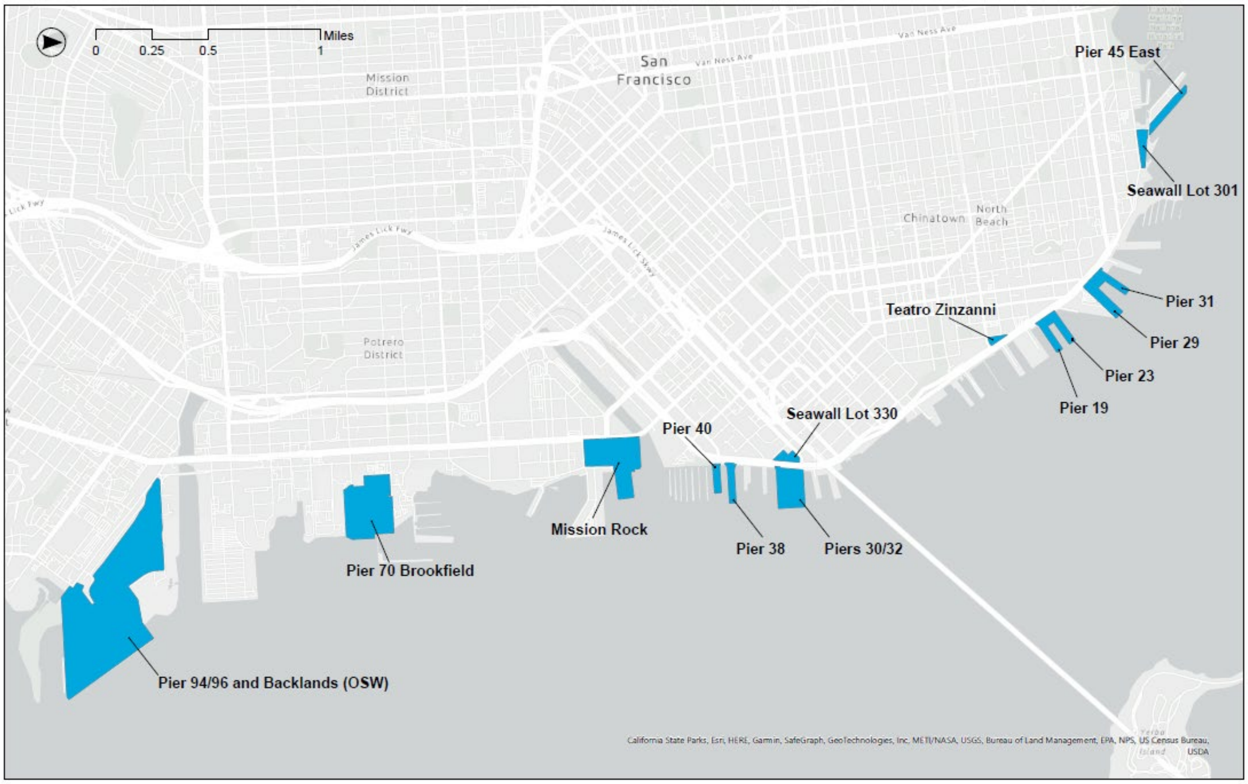


Figure A-13: Planned Development along the Waterfront on POSF Property

POSF requires consideration of SLC for all new developments. The City requires a similar assessment for all projects along the shoreline. As a result, all new projects along the San Francisco shoreline will incorporate coastal flood risk management measures that include raising grades, raising shorelines, adaptation spaces along the shoreline, monitoring of flood events/coastal storms, and the requirement for funds to be set aside and used for SLC adaptation, when needed, and flood proofing at specific sites.

A-4.1.3.4 Planned Resilience Projects

In 2018, San Francisco voters passed Proposition A, a $425 million municipal bond measure, to fund seawall earthquake safety and resilience projects along the Embarcadero waterfront. This money is being used for planning, design, and implementation of Early Projects along the Embarcadero, focused on immediate life safety, disaster response, and earthquake resilience.

POSF identified 23 Embarcadero Early Projects to reduce earthquake and flood risk focused on improving earthquake safety, building City and regional disaster response capability, and reducing near-term coastal flood risk. The estimated total cost range to deliver all 23 projects is estimated between $650 million and $3 billion, more than current funding available from Proposition A and other available funding sources.

POSF prioritized seven Embarcadero Early Projects to move forward through pre-design. The projects include earthquake safety projects to reduce loss of life in an earthquake, earthquake resilience projects to reduce damages from earthquakes to buildings and structures, and a near-term flood improvement project, the Downtown Coastal Resilience Project.

The seven projects are:

- Wharf J9 Replacement and Resilient Shoreline Project
- Pier 15 Bulkhead Wall and Wharf Substructure Earthquake Safety Retrofit Project
- Pier 9 Bulkhead Wall and Wharf Substructure Earthquake Safety Retrofit Project
- Ferry Building Seawall and Substructure Earthquake Reliability Project
- Downtown Coastal Resilience Project
- Pier 24½ to Pier 28½ Bulkhead Wall and Wharf Substructure Earthquake Safety Project
- Emergency Fire Water System Fireboat Manifold Earthquake Resilience Project

These projects are not included in the FWOP condition because the City has not completed analysis of these projects under the California Environmental Quality Act nor approved funding for construction. As plan refinement progresses, the PDT will continue to evaluate how projects such as the Wharf J9 Replacement and Resilient Shoreline Project and the Downtown Coastal Resilience Project will align with elements of the TSP. POSF does not have other significant sources of funding to pay for flood resilience projects, outside of the potential San Francisco Waterfront Coastal Flood Study Recommended Plan. POSF has a significant maintenance capital backlog of $2.2 billion, with an annual budget of $10-15 million for port upkeep and capital state of good repair.

With any available funds, POSF will continue to prioritize immediate life safety and resilience projects over time, similar to the Embarcadero Early Projects. While the City and POSF have a demonstrated commitment to managing flood risk, the coastal flood resilience structures required to manage flood risk along the POSF's 7.5-mile shoreline over the 100-year POA exceeds the capacity of the City or POSF to implement without federal participation.

A-4.1.3.5 Heron's Head Shoreline Resilience Project

The Heron's Head Park Shoreline Resilience Project aims to bring a living shoreline approach to address significant subsidence and erosion since the park's creation over 20 years ago. POSF completed planning, design, and permitting of a nature-based solution to shoreline erosion at Heron's Head Park in 2021. The Heron's Head Park Shoreline Resilience Project will restore the former type and extent of habitat and provide new habitat in the form of coarse sand/gravel beach, new wetland vegetation to reinforce shoreline and pond edges, and subtidal oyster reefs. The coarse material shoreline will enable wetlands to migrate with rising sea level so that some wetland habitat and public access areas remain through mid-century.

The objectives of the Heron's Head Park Shoreline Resilience Project are:

- Protect the southern shoreline from continued erosion
- Restore native wetland plant habitat by growing, planting, and caring for key wetland species
- Create capacity for adaptation to SLR
- Create youth employment and community engagement opportunities

To achieve these objectives, the project includes the following elements:

- Dynamically stable sand and gravel beach
- Oyster reef balls, which are structures fabricated of special concrete, sand, rock, and shell
- Wetland revegetation
- Youth employment in hands-on habitat restoration and community outreach
- Post-construction monitoring and habitat stewardship

A-4.1.4 FWOP Condition Flood Damages

A-4.1.4.1 National Economic Development Flood Damages

Generation II Coastal Risk Model (G2CRM) is a computer model that implements an object-oriented probabilistic life cycle analysis model using Monte Carlo simulation. Monte Carlo simulation is a numerical-analysis procedure that computes the expected value of damage while explicitly accounting for uncertainty in the basic parameters used to determine flood inundation damage. The output is a probability distribution of outcomes that represents the range of potential damages and the probabilities of these possible outcomes.

G2CRM provides integrated hydrologic engineering and economic risk analysis during the formulation and evaluation of flood damage reduction plans in compliance with policy regulations ER 1105-2-100 *Planning Guidance Notebook* and ER 1105-2-101 *Risk Analysis for Flood Damage Reduction Studies*. Uncertainty in storm inputs, economic variables, and depth-percent damage functions are quantified and incorporated into evaluation of the FWOP condition and the performance of any proposed alternatives.

Coastal storm modeling inputs, depth-percent damage functions, structures, and critical infrastructure within the study area are used as inputs for the G2CRM software. In conjunction with hydrologic modeling, G2CRM also incorporates Historic (Low), Intermediate, and High RSLC analysis in compliance with ER 1100-2-8162 *Incorporating Sea Level Change in Civil Works Programs* and EM 1110-2-1619 *Risk-Based Analysis for Flood Damage Reduction Studies.*

G2CRM is a powerful tool for calculating economic damages whenever damages can be tied to water levels. Within G2CRM, this is done through the creation or application of a depth-percent damage curve: when the water reaches a certain height, relative to an asset's first-floor elevation, a certain amount of damage occurs, relative to the structure's assigned value. This framework is appropriate when evaluating damages to structures or to their contents, but it can also be appropriate when addressing critical infrastructure.

For critical infrastructure, empirical stage-damage curves were created that tie downstream damages, such as a loss of access to the BART to water levels. These downstream effects are inserted into G2CRM as separate assets that can take an amount of damage that is not based on the asset's value itself.

FWOP conditions are used as the base condition over the 100-year POA. For this draft report, the model used the Fiscal Year 2023 Project Evaluation and Formulation Rate (Discount Rate) of 2.5% in accordance with EGM 23-01 Federal Interest Rates for Corps of Engineers Projects for Fiscal Year 2023. In future iterations of the modeling and in updates to this draft report, the price level and discount rate will be updated.

The G2CRM model results verified that areas identified as vulnerable to experience coastal flooding would likely experience damages over the 100-year POA. The 7.5 miles of the San Francisco Waterfront coastline includes over 3,000 assets, including single-family residential, multi-family apartments, commercial structures, industrial facilities, high-value high rises, traditional infrastructure (bridges, piers, utilities, roadways, pump stations), critical infrastructure (wastewater treatment plants, recycling plants, fire stations), Nationally historic structures such as the Ferry Building, and specialized assets such as the Chase Center arena.

The study area also includes considerable assets for the BART and San Francisco Municipal Transportation Agency (SFMTA) including Embarcadero Station, the Central Subway underground system, and light rail transit surface track. In additional to the billions in asset value, these services provide transportation for hundreds of thousands of riders per day. In total, the asset inventory (structure and content) for physical assets is valued at over $60 billion.

By the base year of 2040, many assets in the study area are at risk of significant flooding from the 1% AEP storm and other low-frequency storm events, especially under the High SLC curve. SLC over the 100-year POA will further increase vulnerability of the densely populated urban environment as the frequency and magnitude of damaging events increases. Rising sea levels will exacerbate existing asset exposure while introducing risk from moderate- and even high-frequency storm events, especially for low-lying assets such as the Embarcadero roadway and structures directly adjacent to the waterfront. Interruptions to transportation and critical services could also lead to the deterioration of public health and safety conditions. Retreat from the waterfront will be necessary without intervention.

Inundation represents the physical damages to structure and contents caused by flooding that are captured within G2CRM. In addition to inundation, NED damages for retreat, Operations, Maintenance, Repair, Rehabilitation and Replacement (OMRRR), and SFMTA were also estimated. Retreat represents the FWOP floodproofing, condemnation, and land loss costs. OMRR&R represents the operations and maintenance costs to the existing flood control infrastructure and the costs of rebuilding after a seismic event. SFMTA shows the costs of retrofitting the existing rail infrastructure in the face of rising sea levels.

Appendix E: Economic and Social Considerations describes the G2CRM model and the inputs used for this study. The appendix also details the results of the analysis conducted using G2CRM.

Table A-3 presents a summary of the present value total damages (inundation, retreat, OMRR&R, and SFMTA) for the FWOP condition by reach for the study area.

Table A-3: Total Present Value NED Damages by Reach
(Fiscal Year (FY) 2023 Price Levels; 2.5% Discount Rate)

	USACE Low SLC	USACE Intermediate SLC	USACE High SLC
Reach 1 – Fisherman's Wharf	$375,852,000	$430,227,000	$1,588,650,000
Reach 2 – Embarcadero/Market Street	$729,221,000	$1,576,334,000	$7,849,736,000
Reach 3 – Mission Creek/Mission Bay	$898,963,000	$2,113,359,000	$9,517,446,000
Reach 4 – Islais Creek /Bayview	$1,606,779,000	$1,834,863,000	$3,634,008,000
Total	$3,610,815,000	$5,954,783,000	$22,589,840,000

The study area takes over $22 billion in present value damage under the High SLC curve, almost $6 billion in present value (PV) damage under the Intermediate SLC curve, and $3.6 billion in PV damage under the Low SLC curve. Of note under the Low curve is that 72% of those damages are in the seismic category, meaning less than 30% of the total damage is due to flooding or rising sea levels forcing retreat. Under the High curve, though, the majority of the damage (84%) is driven by flooding or increasing sea levels.

A-4.1.4.2 Regional Economic Development Flood Damages

In addition to the analysis of NED damages described above, the potential regional economic impacts of flooding along the San Francisco Waterfront study area were estimated. The analysis identified how these economic impacts from flooding, also known as RED, affect the Bay Area and the larger California economy.

The Institute for Water Resources RED Procedures Handbook (2011-RPT-01) defines RED impacts as regional losses in employment and/or income under the FWOP condition. Based on guidance from this handbook, the RED analysis evaluates the regional economic consequences of coastal flooding and SLR using FEMA benefit-cost analysis methodologies.

The RED analysis consists of three categories: impacts to critical infrastructure, direct economic impacts, and cascading regional economic impacts. Impacts to critical infrastructure are calculated in G2CRM and are generally expressed in terms of revenue loss to specific public and private transportation and utility assets. Direct economic impacts include direct economic output losses and direct job impacts. Direct economic output losses are also modeled in G2CRM, while direct job impacts are produced by the Impact Analysis for Planning (IMPLAN) software using the G2CRM direct output losses as a model input. These direct losses occur when a building sustains damage and cannot be occupied during repairs and restoration of flooded components. Cascading regional economic impacts include indirect and induced impacts on economic output and jobs, both estimated with IMPLAN, again using the G2CRM direct output losses as a model input. Indirect effects represent impacts on business-to-business purchases in the supply chain, whereas induced effects stem from changes in household income spending, after removal of taxes, savings, and commuter income.

Table A-4 summarizes the RED damages for the FWOP condition.

Table A-4: Summary of RED Damages for FWOP Condition

(FY 2023 Price Levels; 2.5% Discount Rate)

	Present Value		
	Low Sea Level Change	**Intermediate Sea Level Change**	**High Sea Level Change**
Revenue Losses for Critical Infrastructure	$130,000,000	$250,000,000	$500,000,000
Direct Output Losses	$24,000,000	$170,000,000	$1,100,000,000
Cascading Regional Output Loss (CA)	$18,000,000	$150,000,000	$1,100,000,000
TOTAL Losses	$172,000,000	$570,000,000	$2,700,000,000
Job Losses	150	1,200	8,500

A-4.1.5 Reach-by-Reach Exposure to Flood Risk

As the 1% floodplain increases with SLR, the exposure of people, structures, businesses, roads, and critical infrastructure to this flood risk also increases. A reach-by-reach summary of exposure under the three USACE RSLC projections is provided in the following subsections.

A-4.1.5.1 Reach 1

The magnitude of flooding and associated exposure in Reach 1 is lowest across the study area (**Table A-5** and **Figure A-14**: Reach 1 Inundation Map). However, Reach 1 contains some of the lowest baseline job earnings (16% of jobs earn $1,250 per month or less) and are dependent on tourism across the waterfront for viability. Such jobs are generally not resilient to disruption (regardless of source) because of limited healthcare benefits and no ability to telecommute.

Table A-5: Reach 1 Exposure to Flood Risk, 2090

	USACE Low	USACE Intermediate	USACE High
Health and Safety			
Social Vulnerability	High concentration of non-white (38%) and aged (over 65) (16%) residents affected		
Residents Exposed	42	86	1,283
Disaster Response Assets Exposed	0	1	11
Economic Vitality			
Direct Job Exposure (mostly restaurant)	159	437	4,212
Legacy Business Exposure	0	2	5
Leisure and Recreation (44,670 daily estimated users)			
Streets Exposed (miles; access)	0	0.3	3.5
Parks and Open Space Exposed (acres)	0.8	2.5	10.2

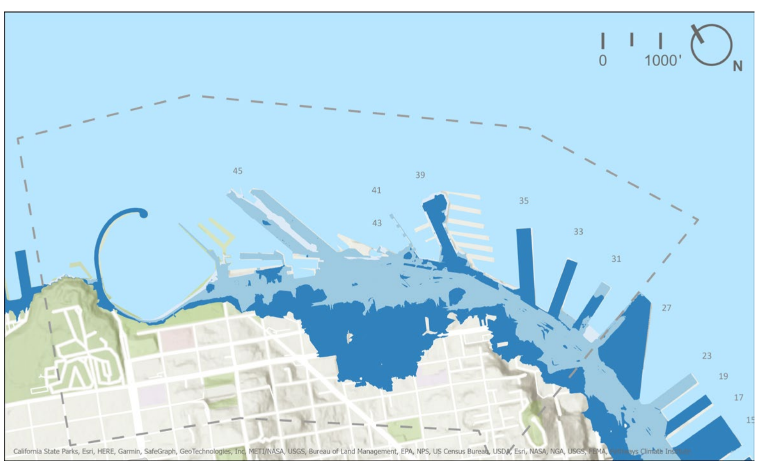


Figure A-14: Reach 1 Inundation Map

A-4.1.5.2 Reach 2

Reach 2 experiences a daily net job inflow of 220,000 workers that rely on a functioning transportation network. Disruption to Embarcadero Station may occur as early as 2040 with a 1% AEP flood event. Additionally, this reach has potential to see the most jobs lost due to flooding (**Table A-6** and **Figure A-15**).

Table A-6: Reach 2 Exposure to Flood Risk, 2090

	USACE Low	USACE Intermediate	USACE High
Health and Safety			
Social Vulnerability	High concentration of non-white (42%) and aged (over 65) (18%) residents affected		
Residents Exposed	341	1,566	4,709
Disaster Response Assets Exposed	1	5	15
Economic Vitality			
Direct Job Exposure (mostly office)	3,912	25,309	75,518
Legacy Business Exposure	0	2	5
Leisure and Recreation (12,030 daily estimated users)			
Streets Exposed (miles; access)	0.8	3.4	8.4
Parks and Open Space Exposed (acres)	3.2	12.6	25.3

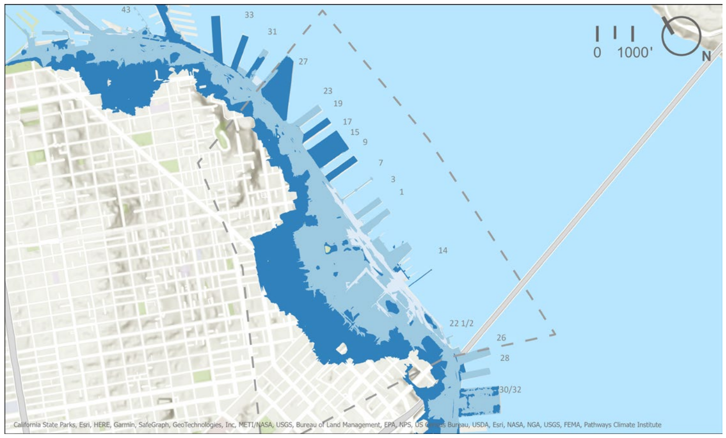


Figure A-15: Reach 2 Inundation Map

A-4.1.5.3 Reach 3

Reach 3 sees the earliest and largest displacement of residents along the waterfront, with potentially permanent residential relocation occurring by 2080. This is significant because Reach 3 also contains 75% of all affordable housing units across the waterfront. This reach is also a main transportation corridor connecting more than 27,500 people through this area daily via the Muni Metro T Third Line, and high-use roadways and Third and Fourth Street bridges (**Table A-7** and **Figure A-16**).

Table A-7: Reach 3 Exposure to Flood Risk, 2090

	USACE Low	USACE Intermediate	USACE High
Health and Safety			
Social Vulnerability	High concentration of non-white (48%) and linguistically isolated (13%) residents affected		
Residents Exposed	1,242	5,301	15,965
Disaster Response Assets Exposed	0	1	16
Economic Vitality			
Direct Job Exposure (mostly entertainment)	1,275	7,487	28,456
Legacy Business Exposure	1	2	6
Leisure and Recreation (39,940 daily estimated users)			
Streets Exposed (miles; access)	2.3	8.3	22.2

Parks and Open Space Exposed (acres)	7.2	13.4	35.0

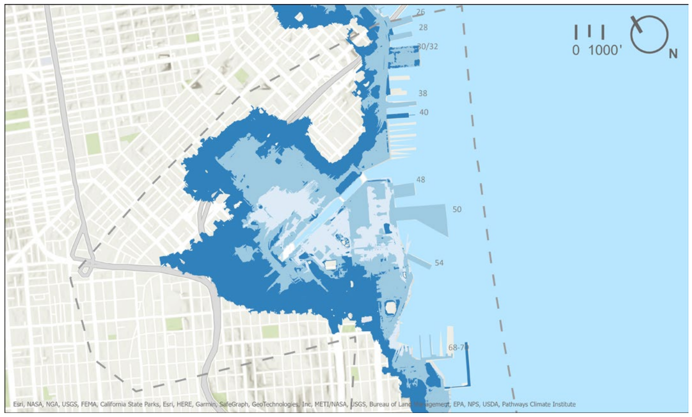


Figure A-16: Reach 3 Inundation Map

A-4.1.5.4 Reach 4

Reach 4 is the first to see significant number of properties affected by repetitive flooding, putting industrial and maritime functions and jobs at risk. The Southeast Treatment Plant (wastewater), which serves approximately 2/3 of San Francisco, is exposed to the 1% AEP event under all three SLC curves. The surrounding neighborhoods are Bayview, Dog Patch, and Potrero Hill. Adaptation considerations for residents and businesses center around equity and environmental justice concerns, job loss, HTRW, gentrification, and open space access(**Table A-8** and **Figure A-17**).

Table A-8: Reach 4 Exposure to Flood Risk

	USACE Low	USACE Intermediate	USACE High
Health and Safety			
Social Vulnerability	Highest concentration of non-white (41%) and single parent families with children (20%) residents affected		
Residents Exposed	266	336	558
Disaster Response Assets Exposed	5	5	9
Economic Vitality			
Direct Job Exposure (mostly entertainment)	1,430	2,412	4,650
Legacy Business Exposure	0	0	4

Leisure and Recreation (6,800 daily estimated users)			
Streets Exposed (miles; access)	2.3	4.0	8.0
Parks and Open Space Exposed (acres)	21.6	25.0	31.1

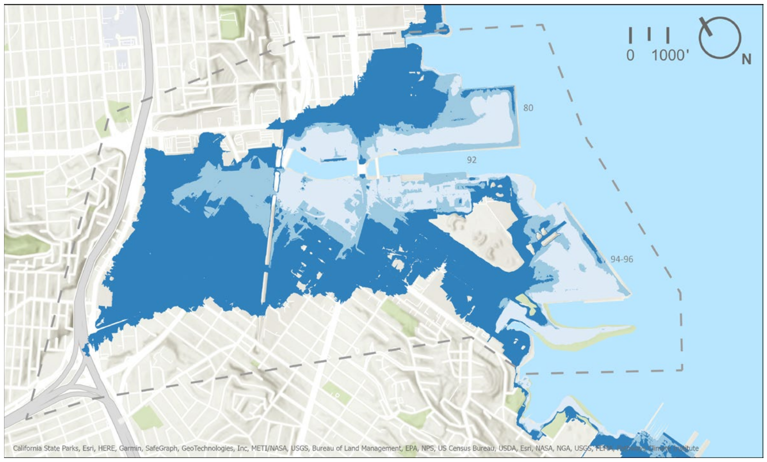


Figure A-17: Reach 4 Inundation Map

A-4.2 Study Area Opportunities

Opportunities are positive conditions in the study area that may result from implementation of a Federal project. This study presents opportunities to:

- Provide resilience and related benefits to communities that have historically been subject to disinvestment and environmental injustice
- Design coastal flood defenses that also reduce earthquake risk to the waterfront and structures connected to the shoreline
- Align multiple federal and regional agencies to coordinate resilience investment in infrastructure sustainability and hardiness over multiple scenarios and conditions – with efficiency gains through coordinated actions and expenditures
- Educate the public and stakeholders about current and future flood risk and create incentives for residents and businesses in the future floodplain to take individual action to reduce flood risk exposure
- Design coastal flood defenses that also improve wildlife habitat and reduce shoreline erosion through addition of Natural and Nature-Based Features that mimic coastal processes
- Develop innovative strategies for adapting vulnerable historic maritime resources to SLR consistent with the Secretary of the Interior Standards for Treatment of Historic Properties

- Recognize the cultural experiences and traditions of diverse waterfront communities and incorporate them into the planning and design of adaptation strategies
- Include opportunities to redesign streets and open space for water retention and storage and green infrastructure to address overland flooding issues and reduce transport of land-based pollutants into the Bay
- Include opportunities to expand waterfront access, open space, and recreation, and enhance the quality and experience of waterfront public space, including the San Francisco Bay Trail and San Francisco Bay Water Trail
- Minimize carbon emissions from major construction by exploring and utilizing proven technology in materials and landscape design

A-4.3 Planning Goals, Objectives, and Constraints

A-4.3.1 Planning Goals

Three broad study goals were identified to develop and implement a resilience strategy to address the multiple risks within the study area. These goals complement the larger resilience efforts proposed by the City of San Francisco in their Resilient SF initiative that will align City agency actions to achieve long-term capability to survive, adapt, and grow within an area with multiple hazards:

- Plan and Prepare: Characterize the multiple study area risks and consequences to inform the range of potential responses and appropriate timing of risk reduction investments to complement and sustain the area's uses, economic and maritime activity, cultural and historic significance, and residential centers.
- Empower resilience investments: Define an innovative long-term menu of responses to increasing risk that will coordinate or launch cost-effective resilience actions from the City and regional agencies. Align investment with future needs for cost-effective and timely implementation.
- Develop a cost-effective method for addressing flooding risk dominated by uncertain timing of RSLC.

A-4.3.2 Federal Objective

In accordance with ER 1105-2-103, the Federal objective for water resource investments must reflect national priorities, encourage economic development, and protect the environment. In addition, federal investments in water resources should reasonably maximize all benefits, with appropriate consideration of costs. Public benefits encompass environmental, economic, and social goals, including monetary and non-monetary effects, and allow for the consideration of quantitative and qualitative metrics (CEQ, 2013).

The Federal objective is to maximize economic, environmental, and social net benefits to the nation, and as such, it does not seek to identify specific targets within objectives. The planning process includes formulation of alternative plans to maximize benefits relative to costs.

A-4.3.3 Planning Objectives

The overarching goal of this study is to formulate alternatives for coastal flood risk management to determine if Federal participation in reduction of the damage to assets caused by coastal flooding within the study area is feasible.

Specific study objectives have been developed to provide a means of determining whether individual management measures can solve the study area's problems while taking advantage of the opportunities identified and avoiding the constraints. The following study objectives have been developed based on the problems, opportunities, goals, and Federal objectives:

- Reduce risk to human health and safety from coastal hazards and flooding due to sea level rise, wave run up and precipitation (combined flooding) in the City of San Francisco
    - Metric: Quantitative and qualitative analysis of how a project would reduce health and safety risks related to population exposure, shelter needs, and access to emergency services and evacuation routes
    - Metric: Quantitative and qualitative analysis of wastewater service impacts to public health
    - Metric: Quantitative and qualitative analysis of contaminated site exposure and potential health impacts
- Reduce costs and risks to NED associated with coastal hazards and combined flooding to business, residents, and infrastructure in the City of San Francisco
    - Metric: Dollars of physical damages reduced for buildings and infrastructure as calculated by G2CRM
    - Metric: Dollars of avoided debris removal and OMRR&R costs as calculated by G2CRM and the PDT
    - Metric: Dollars of land value lost due to monthly flood inundation
    - Metric: Qualitative description of inland flooding avoided
- Improve the resilience of the local and regional economy to impacts from coastal hazards and combined flooding
    - Metric: Dollars of sales and revenue lost due to business disruptions and relocation as calculated by G2CRM and IMPLAN

  - Metric: Quantitative and qualitative analysis of job exposure and changes to regional tourism spending
- Maximize social benefits and improve resilience of affected communities to impacts from coastal hazards and combined flooding
  - Metric: Quantitative and qualitative analysis of population displacement, housing affordability challenges, exposed cultural and historical assets, and community access to resources
  - Metric: Qualitative analysis of disproportionate effects of displacement and limited community access on underserved communities
- Minimize disproportionate impacts to vulnerable communities, including low income and communities of color
  - Metric: Disproportionate effects on underserved communities
- Minimize disruption to maritime facilities and functions caused by coastal hazards and combined flooding, through resilience strategies that support cargo shipping, cruise, ferry and water taxis, excursion boats, fishing, ship repair, berthing, harbor services, recreational boating, and other water-dependent activities
  - Metric: Acreage of maritime backlands lost relative to existing space
  - Metric: Lineal feet of deep draft berthing relative to current berthing capabilities
- Maximize resilience of City transportation infrastructure that is essential to the daily operations and functioning of the city
  - Metric: Quantitative and qualitative analysis of transit corridor disruptions
  - Metric: Dollars in opportunity costs to daily mobility patterns calculated using the Travel Cost Method, as well as revenue loss for BART and Muni
- Minimize damages from coastal hazards and combined flooding to historic resources and preserve the maritime history of the waterfront
  - Metric: Dollars of physical damages reduced for historic resources as calculated by G2CRM
  - Metric: Square footage of historic resources adapted/maintained
- Maximize ability and flexibility to respond to uncertain rates of RSLC
  - Metric: Regret of under-investment or over-investment ($)
  - Metric: Robustness of plan and adaptation pathways across SLC scenarios, including scenarios where predicted earthquakes occur before and after construction of initial investments
  - Metric: Qualitative analysis of predicted post-earthquake Federal disaster investment in repair or replacement of flood defenses ($)

    - Metric: Qualitative assessment of availability of adaptation pathways by reach, including:
        - Assessment of foundation for future adaptation across SLC scenarios
        - Time required to plan, fund, design, and construct adaptations
        - Effects of multiple disruptions
    - Metric: Efficiency of Federal and local investment across SLC and earthquake risk scenarios, factoring in discount rates and construction cost inflation
- Leverage public investment in coastal flood risk reduction to reduce earthquake risks
    - Metric: Qualitative analysis of efficiency of Federal and local investment based on earthquake risk scenarios
- Maximize environmental benefits, sustainable approaches in project design and construction, and consideration of coastal processes
    - Metric: Quantitative and qualitative analysis of physical change to water quality and store floodwaters
    - Metric: Quantitative and qualitative analysis of the value added to the biological environment, including species habitat
    - Metric: Qualitative analysis of embodied carbon and reduced greenhouse gas emissions associated with low- or zero-carbon concrete and building materials
- Promote and enhance public access to the San Francisco waterfront and the Bay and minimize disruptions to waterfront access and use
    - Metric: Dollars of willingness to pay for waterfront recreation opportunities
    - Metric: Quantitative and qualitative analysis of compliance with public access requirements
    - Metric: Quantitative and qualitative analysis of open space recreation, bike, and pedestrian routes
- Preserve, defend, and adapt existing housing, community services and facilities (e.g., libraries, community centers, health centers, homeless shelters, etc.), and cultural and historic resources from rising sea levels and coastal flooding
    - Metric: Housing affordability indicators
    - Metric: Displaced population
    - Metric: Shelter needs

- Metric: Community services
- Metric: Cultural and historic resources
- Metric: Community access

A-4.3.4 USACE Resilience Objective

The second objective of this study focuses on resilience. In EP 1100-1-2 USACE Resilience Initiative Roadmap, USACE identified four key principles of resilience from the many definitions of resilience that exist. These principles – Prepare, Absorb, Recover, and Adapt – identify the temporal aspects and actions that are necessary to build community resilience capacity.

Prepare: The study will outline the likely FWOP condition and assess structural and nonstructural actions that may reduce that risk. Communities and agencies can make informed choices to address existing coastal flooding risk. Proactive measures, either through individual action, land use policies, and/or coordinated action, can increase preparedness ahead of flood events and make assets within areas prone to future coastal flooding with SLR more resilient to these hazards.

Absorb: This study includes measures that will reduce risk and sustain function of infrastructure and community resources during and after exposure to coastal flooding.

Recover: This study evaluates solutions that not only reduce damages, but also reduce the resulting downtime of key community and area resources and critical infrastructure following coastal flooding events, and allow quicker recovery before, during and after storms.

Adapt: This study recognizes adaptation as a key component for risk reduction under uncertain timing of RSLC and will identify compatible structural and nonstructural measures that may be implemented as risk increases. A monitoring plan, with pre-identified technical experts to assess risk and adapt area defenses, will improve cos-effective response at appropriate points in times.

A-4.3.5 Federal Environmental Objectives

USACE strives to balance the environmental and development needs of the nation in full compliance with NEPA and other authorities provided by Congress and the Executive Branch. Public participation is encouraged early in the planning process to help define problems and environmental concerns relative to the study. Therefore, significant environmental resources and values that would likely be impacted, favorably as well as adversely, by an alternative under consideration are identified early in the planning process. All plans are formulated to avoid, to the fullest extent practicable, any adverse impact on significant resources. Significant adverse impacts that cannot be avoided are mitigated as required by Section 906(d) of Water Resources Development Act (WRDA) of 1986.

This document is a draft IFR and EIS. As with a separate NEPA document, it documents the environmental effects of the Recommended Plan and summarizes compliance with Federal statutes and regulations.

A-4.3.6 Environmental Operating Principles

Consistent with NEPA, USACE has formalized its commitment to the environment by creating a set of Environmental Operating Principles applicable to all its decision making and programs. These principles foster unity of purpose regarding environmental issues and ensure that environmental conservation, preservation, and restoration are considered in all USACE activities. This report includes a discussion of the USACE Environmental Operating Principles and how the study addresses them.

A-4.3.7 Planning Constraints

A constraint is a restriction that limits the extent of the planning process; it is a statement of effects that alternative plans should avoid. Constraints are designed to avoid undesirable changes between FWOP and FWP. All studies must avoid conflict with Federal regulations, as stated in Federal law, USACE regulations, and executive orders. The following constraints have been developed for this study:

- Avoid actions that may violate authority of the Port Commission to fulfill its public trust responsibilities consistent with the Burton Act (Chapter 1333 of the Statutes of 1968)
- Maintain permitted public access, such as the San Francisco Bay Trail, San Francisco Bay Water Trail, and Blue Greenway
- Maintain ecological functions and minimize ecological disruptions in the Bay
- Minimize aesthetic impacts to the study area and its resources
- Minimize impacts to cultural, historic, and community resources that sustain national and regional continuity wherever possible
- Do not exacerbate ability of inland drainage system to manage stormwater runoff and do not increase combined sewer overflows to the Bay (Clean Water Act requirements)
- Avoid hazardous, toxic, and radioactive waste sites or address the risk consistent with an improved risk mitigation plan

Several considerations were identified for plan formulation and evaluation that will reflect the City of San Francisco’s overall planning values and priorities and will support community resilience, which is an integral component of the long term vision for the study area.

- State law requires municipalities to adopt a Housing Element that identifies programs for preservation, improvement, and development of housing, and a

Housing Element implementation program that conserves and improves the condition of affordable housing, including mitigating loss of housing units[5]

- Avoid major loss of existing housing or impacting available space for additional housing creation. Regional and local housing mandates (as described in Plan Bay Area and the Housing Element of the SF General Plan) set housing targets for San Francisco, tied to funding and policy triggers. Achieving those targets necessitates that the City avoid major loss of existing housing and create available space through zoning.

Section A-5. Plan Formulation Strategy

Plan formulation in response to the study authority was conducted in two broad phases. An initial planning iteration considered distinctly different conceptual approaches to manage the coastal flood risk in the region. The USACE San Francisco District PDT conducted an initial screening of the conceptual approaches including a deployable water management structure at the Golden Gate Bridge, an offshore wave attenuator, several scales of offshore barriers, perimeter plans along the Bay coastline and two forms of retreat.

The second and most significant phase of plan formulation assessed cost-effective approaches to the perimeter plan and retreat. The PDT developed a focused array of alternatives and evaluated NED benefits and costs for the three RSLC conditions (USACE Low, Intermediate, and High curves) to identify the NED plan for each condition. The PDT then developed a Total Net Benefits Plan to add to the three NED plans in the final array of alternatives. The TNBP was developed as a combination of varied reach-level components of the focused array. A total benefits analysis of the final array was then conducted across all four P&G accounts for each of the three RSLC conditions to identify the TNBP. As a final step, the TSP was identified. Further development of the TSP will be conducted for the final IFR/EIS.

Figure A-18 illustrates the plan formulation strategy. A detailed summary of the formulation and screening is provided in subsequent sections.

[5] **CA Government Code Section 65583 (excerpts).**

The housing element shall consist of an identification and analysis of existing and projected housing needs and a statement of goals, policies, quantified objectives, financial resources, and scheduled programs for the **preservation, improvement,** and development of housing.
Related to implementation programs for Housing Elements:
65583. (c)(4) Conserve and improve the condition of the existing affordable housing stock, which may include addressing ways to mitigate the loss of dwelling units demolished by public or private action.

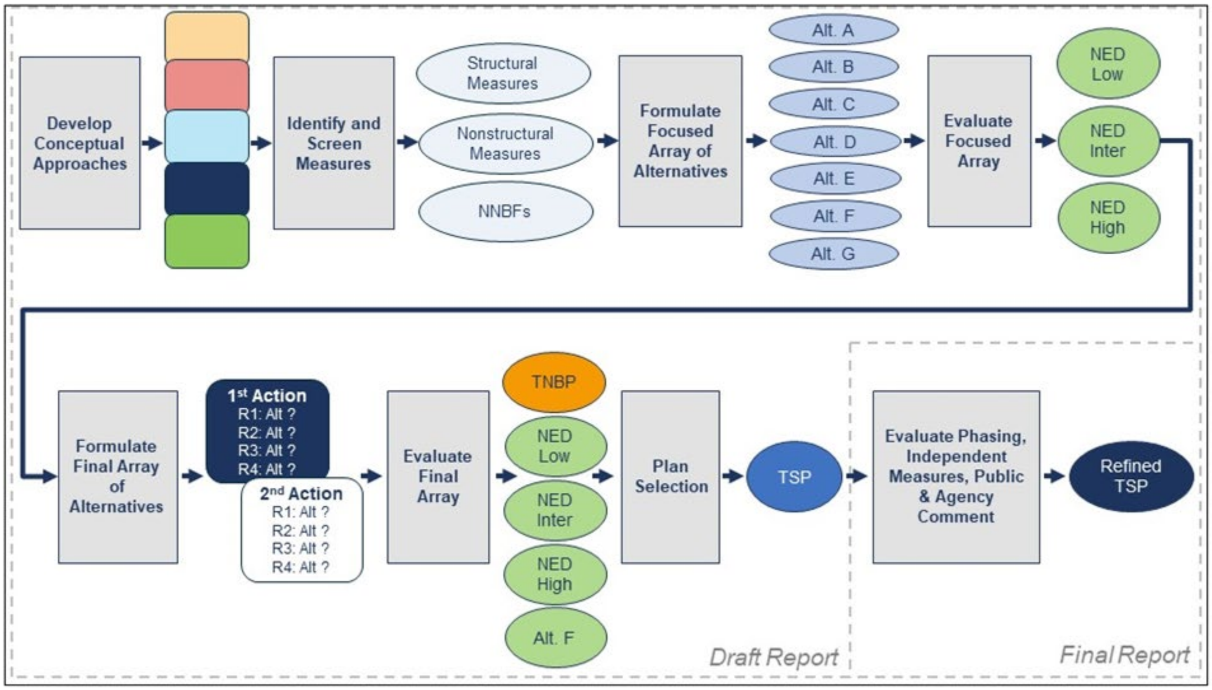


Figure A-18: Plan Formulation Strategy

Seismic risk can be described probabilistically. Coastal flooding will increase at an uncertain rate over the POA. Although coastal flood events may occur in the study area, the scale of flood event is primarily influenced by the water surface elevations that result from a coastal flood event in combination with SLR. The variability of water surface elevations (WSEs) that result from the 0.1% AEP and the 1% AEP vary by less than 2 feet in WSE. The primary risk to address is higher WSE, thus the appropriate measures would address elevated water through structural and nonstructural approaches. As a result, the plan formulation strategy sought to identify different approaches to reduce flood risk now and into the future with an array of alternatives that would inform whether early, phased, or later interventions would be most cost effective and avoid or minimize study area impacts.

Three elements were applied to develop an array of alternatives for this study, which are consistent with the formulation guidance referenced above to ensure delivery of a policy-compliant report and recommendations. The three elements are:

- Overall approach to reduce risk consisting of structural and nonstructural measures and natural and nature-based features (NNBFs) (in line with the EWN philosophy) along the existing shoreline, more bayward, and more inland alignments (called lines of defense (LODs))
- Varied scales of features to reflect uncertain timing of RSLC
- Phased implementation of features within most alternatives

A-5.1 Conceptual Approaches

In 2018 at the start of the study, the PDT developed 11 conceptual structural approaches on a horizontal alignment, referred to as the LOD using a range of appropriate measures to form the initial array of alternatives, shown in **Table A-9**. These initial conceptual approaches were evaluated and screened based on completeness, effectiveness, efficiency, and acceptability in consultation with representatives from City and regional agencies and resource and regulatory agencies.

Table A-9: Initial Conceptual Approaches with Screening

Approach	Description	Theme	Benefits	Reason Screened or Retained
Barrier at Golden Gate Bridge	Deployable barrier or permanent gate with locks at or near the Golden Gate Bridge.	Regional reduction in coastal flood risk.	Large scale reduction in coastal storm damages.	**Screened:** Extremely costly. Endangered species impacts, water quality, in-Bay fill, and governance issues make plan unacceptable
Offshore Wave Attenuator	Offshore wave attenuator from Aquatic Park to Pier 80 where the project moves to a water's edge with piers alignment until the mouth of Islais Creek. There is a barrier at the mouth of Islais Creek with the alignment resuming at the water's edge (with piers) from Pier 94/96 to Heron's Head Park.	Preserves maritime environment, existing over-water structures and waterfront uses; least disruptive approach.	Lower cost than offshore wall. Short-term flood risk management. Short-term historic preservation.	**Screened:** Endangered species impacts, water quality, and in-Bay fill make plan possibly unacceptable. Least cost-effective plan.
Offshore Barrier - Entire Study Area	Offshore seawall with gates to support the movement of marine traffic from Aquatic Park to Heron's Head Park.	Preserves maritime environment, existing over-water structures and waterfront uses; least disruptive approach.	Minimally disruptive long-term flood risk management with historic preservation.	**Screened:** Endangered species impacts, water quality, and in-Bay fill make plan probably unacceptable
Offshore Barrier until Pier 50	Offshore barrier with gates to support the movement of marine traffic from Aquatic Park to Pier 80 where the project moves to a water's edge with piers alignment	Preserves maritime environment, existing over-water structures and waterfront	Minimally disruptive long-term flood risk management with historic preservation. Opportunity for	**Retained:** In-Bay fill, and partial water quality issues make plan less desirable, but still possibly acceptable

Approach	Description	Theme	Benefits	Reason Screened or Retained
	until the mouth of Islais Creek. There is a barrier at the mouth of Islais Creek with the alignment resuming at the water's edge (with piers) from Pier 94/96 to Heron's Head Park.	uses; low disruption approach.	restoration south of Islais Creek.	
Balanced Alternative	Offshore solution extending from Aquatic Park to Pier 14 where the project moves to a water's edge with piers alignment (including barriers at the mouths of Mission Creek and Islais Creek) until Heron's Head Park.	Preserves the historic core in the North with a "return to the Bay" in the south.	Minimally disruptive long-term flood risk management; historic preservation; environmental restoration.	**Retained:** In-Bay fill, and partial water quality issues make plan less desirable, but still possibly acceptable
Heritage Plan	Pier end alignment with a project connecting Aquatic Park to Pier 45. Project continues along pier ends to Pier 14 where the alignment moves to water's edge with piers. The project resumes its pier end alignment at Pier 24, continuing to Pier 50 where it becomes a water's edge with piers alignment until Heron's Head Park. There are barriers with gates at both creek mouths.	Maximum historic preservation with opportunities for pier restoration (as opposed to offshore approaches). Pier-centric approach.	Lower cost than offshore plans with greater pier preservation potential and some seismic benefits (to piers).	**Retained:** Appears acceptable, possible view/aesthetics issues

Approach	Description	Theme	Benefits	Reason Screened or Retained
New Seawall	Water's edge with piers alignment from Aquatic Park to Pier 45, where it becomes a new nearshore seawall extending south to Pier 50. The northern-waterfront alignment briefly becomes water's edge with piers to accommodate the Ferry Building. South of Pier 50, the alignment is water's edge with piers to the end of the project at Heron's Head Park. There are barriers at both creek mouths.	New seawall; multi-hazard risk management. Includes assumption of incidental seismic benefits.	Long-term flood risk management that reduces seismic vulnerability and offers more space to allow for natural shoreline opportunities.	**Retained:** In-Bay fill issue, otherwise Plan appears acceptable
Depend on the Piers	Water's edge with piers alignment from Aquatic Park to Pier 50 where the alignment becomes water's edge without piers until Heron's Head Park. Barriers at both creek mouths.	Piers provide flood risk management, which is a medium-term solution.	Offers the opportunity for some seismic improvement to piers and seawall, and medium-term flood risk management.	**Retained:** Plan appears acceptable, possible view/aesthetics issues
Shoreline Defense	Beach nourishment at Aquatic Park with a water's edge without piers alignment throughout the remaining project area. Barriers at both creek mouths. Potential flood proofing of select pier structures and construction of new select piers.	This is a no-pier defense solution that reduces flood risk at the shoreline (with additional solutions at some piers).	Offers the opportunity for long-term flood risk management without relying on stability of existing piers. May enable construction of some new piers.	**Retained:** Plan appears to be acceptable, possible access issue to over-water structures
Living with Water	Alignment along first inland roadway from Aquatic Park to 19th Street where the project takes advantage of high ground until 23rd Street, at which point it resumes along the roadway (23rd to Cargo Way; Illinois Street from Cargo Way to Jennings; Jennings St until Evans Street where	Embracing the water.	This is a potentially lower-cost solution that accepts our vulnerability to rising waters.	**Retained:** Least costly, but Benefit-Cost Ratio expected to be > 1

Approach	Description	Theme	Benefits	Reason Screened or Retained
	the project ends).			
Full Managed Retreat	Retreat to high land.	Return to the original shoreline.	Significant and long-term reduction in flood risk.	**Screened:** Most acceptable plan to regulatory agencies but screened due to very low efficiency

These conceptual approaches were presented at the Alternatives Milestone Meeting on December 3, 2018, and the San Francisco Port Commission on February 12, 2019.

In consultation with representatives from City and regional agencies, and resource and regulatory agencies, the PDT began developing conceptual alternatives based on themes. The themes used to organize the preliminary array were:

- Seismic safety and disaster response
- Historic and cultural preservation
- Transportation-mobility
- Ecological assets and services
- Community cohesiveness
- Nonstructural

Preliminary analysis of these conceptual alternatives confirmed that the perimeter plan is the most cost-effective approach to defend the study area against coastal flood risk over the 100-year POA, and the other conceptual approaches were screened from further development or consideration. Work on conceptual alternatives continued through early 2021, when USACE developed new guidance for the study (**Section A-2.2**) to support development of the perimeter plan to balance cost-effective implementation and performance under uncertain timing of RSLC. The guidance provided the following formulation direction:

- Develop multi-hazard formulation strategies that reflect timing, location, and severity differences in risk
- Distinguish between measures to address seismic risks associated with the flood problem; other alternatives that show them coupled; this facilitates the compare and contrast between the alternatives
- Develop at least one stand-alone nonstructural alternative
- Incorporate Engineering with Nature (EWN), when practicable
- Formulate with all three USACE RSLC projections, plus additional State of California projections if a LPP is requested. Formulate measures and alternatives that can be implemented incrementally for varying topography and locations to address varying degrees of risk. Individually, and in combination, they should describe flexibility in scale and timing of actions (initial and future adaptations) for

the desired risk reduction performance as required under the Planning Guidance Notebook

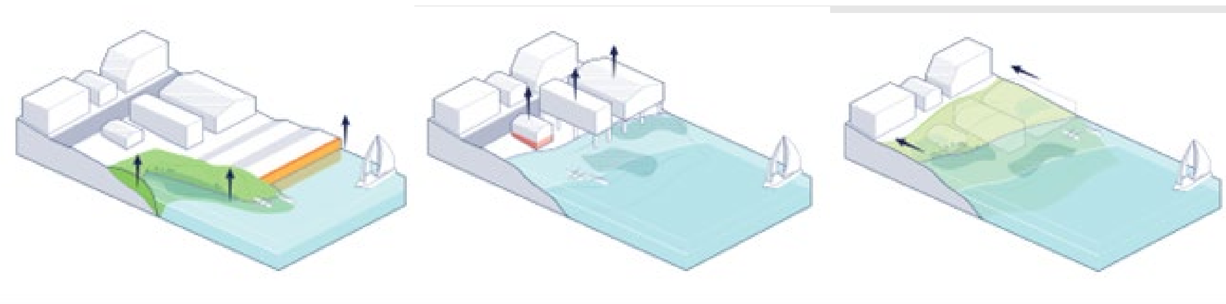
A-5.2 Approaches to Reduce Risk

Instead of formulating and evaluating a plan under one RSLC rate and assessing its performance under all rates, formulation for this study was conducted using three RSLC rates and adapting the scale or timing of the features to manage risk over 100 years.

The timing of SLC is uncertain, so the focused array was formulated to reveal lessons about cost effectively managing flood risk with uncertain timing, whether to retreat or defend, or to build big initially or to build smaller and adapt later. Four broad, conceptual, high-level approaches – Defend, Accommodate, Retreat, and Hybrid – were developed as a basis for formulating plans to address coastal flood risk. By law, at least one entirely nonstructural plan is required. The terms are defined as follows:

- **Defend** means measures will be used to block Bay waters, either at the current shoreline alignment, bayward of the current alignment, or slightly landward of the current shoreline.
- **Accommodate** can include nonstructural measures to live with water, moving the LOD landward as managed retreat to move people and assets away from the water, or a combination of both of these approaches.
- **Retreat** scenarios are designed to “align with watersheds” by advancing the LOD and shoreline landward, while working with natural inland flooding patterns through a series of nonstructural and structural measures. Floodproofing of some buildings and infrastructure would occur in areas of lower risk, while other assets would be moved away from the current Bay shoreline in highest risk areas.
- **Hybrid** means a combination of these approaches could be used throughout the study area based on flood risk and assets.
- NNBFs can be part of all these approaches.

The Defend, Accommodate, and Retreat approaches are illustrated in **Figure A-19.** These approaches can be implemented through alternatives built from measures. Measures are the basic building blocks of a comprehensive approach to addressing coastal flood risk. They are applied based on how they align with short- and long-term goals, current shoreline configuration, existing infrastructure, area of open space (or potential for open space), and conceptual feasibility, among other considerations. The alternatives produced with these approaches supported comparison of costs and benefits of distinct approaches to reduce flood damage from inundation from Bay waters, which consists of stillwater, wave runup, and RSLC. **Table A-10** presents a brief set of example measures as they align with the three approaches.



Defend	Accommodate	Retreat
Keep coastal flood water out, stay in place	*Let coastal flood water in, stay in place*	*Let coastal flood water in, and move out of the area over time*

Figure A-19: Approaches to Reduce Risk

Table A-10: Measure Examples for Approaches to Reduce Risk

Adaptation Approach	Physical Measure Examples	Policy Measure Examples
Defend	Seawalls, levees, floodwalls, gates	Updated flood hazard maps
Accommodate	Floodproofed buildings, relocated sensitive equipment to upper floors, deployable flood barriers (e.g., sandbags)	Robust warning system and preparedness plans, financial and technical support programs for residents and businesses, updated building codes
Retreat	Relocated buildings or sensitive infrastructure to lower-risk areas	Land use and zoning changes, voluntary buyout programs

A-5.3 Lines of Defense and Zones

For each structural alternative, a horizontal alignment, referred to as the LOD, was developed to provide protection against coastal flooding and SLR. **Figure A-20** illustrates this concept. The LOD varies by strategy and by location throughout the waterfront (for example, the LOD can be further inland in one location, compared to right along the existing shoreline or shifted slightly toward the Bay in other locations). The selection of the LOD for each strategy was informed by a preliminary examination of local space constraints (e.g., is there enough space for a gradual versus steep elevation transition) and based on the public realm and urban design assumptions adopted for this effort.

The LOD defines the boundary between two related forms of flooding: an inland flood zone and a coastal flood zone (**Figure A-21**). Raising the shoreline defends against coastal flooding, but it also has the potential to create or exacerbate inland flooding behind the LOD. Inland flooding can be addressed with pumping and with flood resilient buildings and streets. If coastal flood defenses are at the shoreline, the inland flood zone will be larger. If coastal flood defenses are farther inland, there is a big coastal flood zone, reducing the need for as much pumping behind the LOD. The location of the LOD will help to identify what other physical and policy measures are needed to reduce risk in each zone.

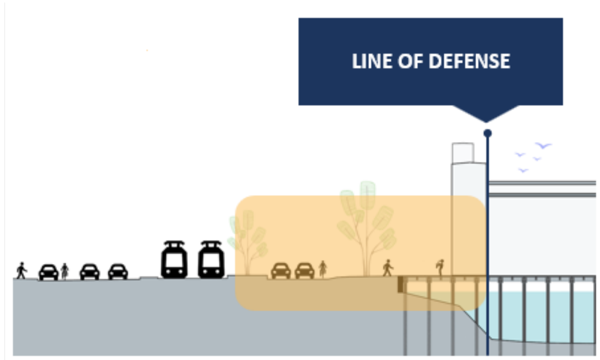


Figure A-20: Line of Defense

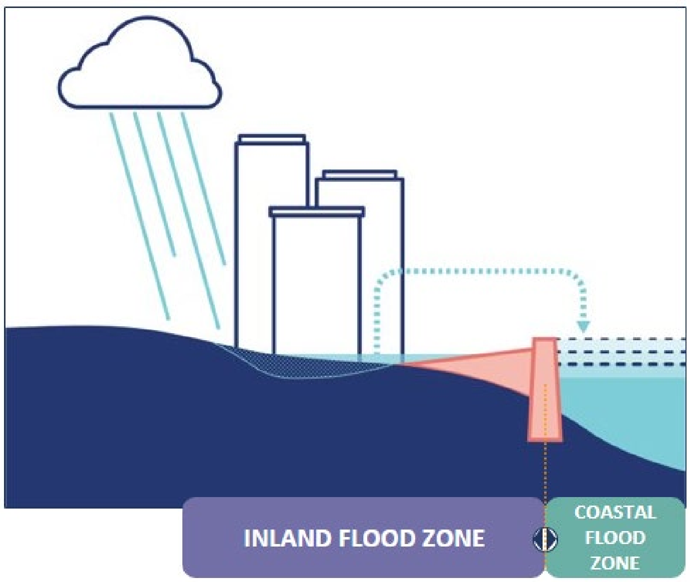


Figure A-21: Flood Zones

A-5.4 Varied Scaling of Features

Within the broad conceptual approaches, the PDT formulated alternatives that vary the scale and timing of the structural and nonstructural strategies to support comparison of cost and performance under the uncertain timing of the RSLC component of the inundation risk. Thus, the array of alternatives includes variations of structural and nonstructural features that are scaled to address varying RSLC conditions:

- One plan is scaled to reduce risk for the low USACE RSLC, with a single action over the study period.

- One plan is scaled to reduce risk at the low rate of RSLC for the initial action, and then adapted to be scaled to the intermediate rate of RSLC for the latter half of the study period.
- Four plans – one nonstructural plan with two possible scales and three structural plans – are scaled to reduce risk at a target performance for intermediate USACE RSLC rate under the first action and high USACE RSLC rate for the second action.

A-5.5 Adaptation as Subsequent Actions

A final aspect of the plan formulation strategy is to identify phased implementation of the features to balance two important criteria for plan selection: cost effectiveness and adaptability to uncertainty across the POA. Adaptations were described in sufficient detail to support estimation of benefits and costs of the alternatives, and scales of adaptation correspond to the target level of performance of each alternative. At this initial stage of plan development, implementation was assumed to occur in a two-step process with the first action occurring in 2040 and second action occurring in 2090. However, a Monitoring and Adaptation Plan (MAP) will ultimately be used to model what the forecasted implementation strategy might look like given the associated risks, and to refine implementation dates. The MAP in Appendix G will ultimately address how USACE and POSF will manage the risks of RLSC over time through implementation of subsequent Federal actions, in congruence with City plans, to outline the need to identify triggers for risk assessment, management, and implementation. The Climate Resiliency MAP would build the framework to include, but is not limited to:

- Identify thresholds of RSLC that would trigger the need for an adaptation, such as additional height to manage coastal flood risk or changed alignment
- Evaluate the plan performance required to address the SLR risk based on those thresholds, considering other factors such as life of asset, other planned projects, and disruption from the construction period
- Develop the governance and executive structure to collaboratively monitor and interpret risk within the study area
- Describe coordination and involvement of resource agencies, USACE, POSF, City, and State to manage the risks over time
- Clarify appropriate scale and alignment of features to be constructed in time to reduce vulnerability to flooding in the study area

A-5.6 Treatment of Seismic Costs

Section 152 of WRDA 2020, as amended by Section 8380 of WRDA 2022, provides for the treatment of certain benefits and costs for flood risk management projects in regions of moderate or high seismic hazard. Specifically, Section 152, as amended, states:

SEC. 152. TREATMENT OF CERTAIN BENEFITS AND COSTS.

(a) IN GENERAL.—In the case of a flood risk management or coastal storm risk management in a region of moderate or high seismic hazard, for the purpose of a benefit-cost analysis for the project, the Secretary shall not include in that analysis any additional design and construction costs resulting from addressing seismic concerns.

(b) SAVINGS PROVISION.—Except with respect to the benefit-cost analysis, the additional costs referred to in subsection (a) shall be—

(1) included in the total project cost; and

(2) subject to cost-share requirements otherwise applicable to the project.

Alternatives were formulated with full consideration of applicable USACE engineering design standards needed to address seismic hazards in the study area. However, in accordance with the requirements of Section 152, as amended, the costs of the features necessary to address seismic concerns were excluded from the NED cost of alternatives and the benefit-cost ratio (BCR). These costs are included in determining the total cost of the TSP and in determining cost-sharing requirements for the TSP.

Section A-6. Identification and Screening of Management Measures

Management measures are features or actions that contribute to the planning objectives. Measures were formulated based on problems in each of the four reaches. They were derived from a variety of sources, including the NEPA scoping process and coordination with stakeholders. Coastal flood risk management measures consist of three basic types: structural measures, nonstructural measures, and NNBFs.

The measures considered for this study can reduce risk alone or in combination. They were screened for applicability, function and space constraints, and anticipated cost effectiveness. Smaller scales of NNBFs are considered for their function to reduce risk in specific applications and to replicate natural coastal processes that are displaced by hardened shorelines. The PDT consulted with the USACE National Nonstructural Committee and incorporated lessons learned from current nonstructural policy concerns and recent coastal flood risk management studies conducted by the USACE New York, Galveston, and New Orleans Districts.

A-6.1 Structural Measures

Structural measures reduce flood risk by modifying the characteristics of the flood. They are physical modifications designed to reduce the frequency of damaging levels of flood inundation. In the context of coastal flooding, structural measures are often employed to defend against overtopping (flood barriers); reduce wave hazards (dissipation); reduce erosion (armoring); and facilitate the flow, storage, or removal of water that has overtopped the shoreline (pumping and drainage). They may be used alone or in combination with other measures.

The structural measures considered in this study are presented in **Table A-11**. Each measure was also screened to determine its applicability in the study area and the results of the screening are also presented in **Table A-11**.

Table A-11: Screening of Structural Measures

Measure	Description	Carried Forward?	Discussion
Storm Surge Barriers	A storm surge barrier is an in-water structure that prevents floodwaters from traveling into an area when its gates are closed. It can include navigable and/or non-navigable gates. For the purposes of this study, this term typically refers to a regional storm surge barrier (e.g., located at the Golden Gate).	No	Feasibility of regional storm surge barrier at the Golden Gate is uncertain, and prior (external) studies have raised concerns including anticipated impacts on water quality, endangered species, regional economy, governance issues, and costs. Given the complex hydrodynamic, geotechnical, and ecological conditions of the Bay, a major engineering and environmental analysis of the Bay would be needed to understand impacts of a storm surge barrier at the Golden Gate.
Floodwalls	Floodwalls are hard, vertical structures built to prevent floodwaters from reaching at-risk areas. They are typically built parallel to the shoreline. Floodwalls can be made out of a variety of materials and designs. Examples include sheetpile walls and T-walls.	Yes	Floodwalls are appropriate for some locations within the study area, especially where space is constrained.
Levees	Levees are earthen structures that are wide at the base and tapered toward the top, made of compacted soil. They can have grassy vegetation on top or can be designed to host walking or biking paths. In coastal environments, they must be designed to include erosion protection. Levees are typically built parallel to the shoreline.	Yes	Levees can represent a lower-cost option than floodwalls, assuming minimal space constraints. Levees are appropriate for some locations within the study area where space constraints allow.
Seawalls and Bulkhead Walls	For the purposes of this report, the terms “seawall” and “bulkhead wall” are used interchangeably. Seawalls are hardened structures parallel to the shoreline to protect from coastal hazards on one side and to retain earthen fill on the other side.	Yes	Seawalls exist along portions of the current waterfront. They are appropriate especially in areas with maritime activities.
Breakwaters	Breakwaters are structures constructed at a coastal area to manage the effects of tides, currents, waves, and storm surges. These measures can be fixed or floating and constructed of a number of different	Tentatively Yes	Breakwaters are in common use around the Bay for reducing wave energy in marinas or, in some cases, recreational or habitat areas. There are several existing breakwaters throughout the study area.

Measure	Description	Carried Forward?	Discussion
	materials and methods, including sheet piles, rubble mounds, and stone. They are typically built in-water near the shoreline.		Breakwaters may be appropriate for consideration in this study at a later stage of design.
Tide Gates	Tide gates are operable structures that apply to waterways such as creeks and rivers that can be closed to reduce flood risk before a storm event or extreme high tides. Tide gates would tie into adjacent shoreline defenses (such as a seawall or floodwall) to prevent outflanking. These structures would be designed to allow boats and other maritime vessels to pass during standard operations. Tide gates are anticipated to require more frequent closure as sea levels rise. Depending on the rate of SLR, they could eventually remain permanently shut.	Yes	Tide gates are in use in multiple locations throughout the Bay. Structure age and condition, vulnerability to rising sea levels, maritime and recreational use, and interactions with ecology and protected species factor into local decision making around barrier construction, rehabilitation, replacement, removal, and operations and maintenance.
Deployable Closure Structures	Deployable closure structures are temporary coastal flood risk management measures that could be deployed manually or passively. For example, a flip-up barrier is a passive deployable flood barrier. The passive deployment mechanism allows deployment of a flip-up barrier without any involvement from operation personnel and is operated by physics (i.e., water pressure) and activated when the design conditions are met (i.e., at the onset of submergence of the base).	Yes	Deployable closure structures will be needed as part of a coastal flood defense system in this study area to allow for pedestrian or vehicular access in constrained locations.
Pump Stations	Structural measures, such as seawalls, levees, and floodwalls, tend to trap rainfall runoff associated with storms on the landward side. Pump stations can be used to redirect water in low-lying elevations to more appropriate locations. They generally have a sustained operation and maintenance commitment as well as associated costs.	Yes	Large pump stations are considered for use as a component of a water control structure at the creeks. Pump stations will also be needed in combination with other inland drainage infrastructure to assist in outflow of runoff.
Inland Drainage Infrastructure	Structural measures, such as seawalls, levees, and floodwalls, tend to trap rainfall runoff associated with	Yes	Inland drainage infrastructure is appropriate throughout the study area. The specific types and

Measure	Description	Carried Forward?	Discussion
	storms on the landward side. Inland drainage infrastructure can include gravity outlets, like culverts installed along the length of the shoreline, as well as conveyance and storage structures.		configuration of inland drainage infrastructure will be determined at a future stage of planning and design.
Revetments	Revetment reduces erosion caused by wave action, storm surge, and currents. Revetment can be incorporated into the design of other structural measures.	Yes	Revetment is commonly used for managing erosion in the Bay.
Bridge Raising/Replacement	Bridge raising consists of raising an existing highway, railroad, or pedestrian bridge that crosses a water body to reduce the risk of floodwaters or high tides damaging the bridge. Raising also removes an impediment to the ability of the water body to pass flood flows or to accommodate high-water levels caused by tides.	Yes	There are four bridges within the study area for which bridge raising/replacement could be appropriate.
Wharf Raising/Replacement	Wharves along the shoreline can be integrated with the seawall to reduce impacts caused by wave action. This measure consists of demolishing the existing wharf and constructing a new wharf at a higher elevation.	Yes	Existing wharves along portions of the shoreline serve multiple purposes, including coastal storm risk reduction.

Notes:
Green means retained for further evaluation.
Yellow means tentatively retained for further evaluation in future stages of planning and design but not currently included in the alternatives.
Red means screened out.

A-6.2 Nonstructural Measures

Nonstructural measures are permanent or contingent measures applied to a structure and/or its contents that prevent or provide resistance to damage from flooding. Nonstructural measures differ from structural measures in that they focus on reducing the consequences of flooding instead of focusing on reducing the flow of water into portions of the study area.

Nonstructural measures can be grouped into two categories: physical and nonphysical measures. Physical nonstructural measures include actions that require modifications to a property or structure. They include structure elevation, dry and wet floodproofing, basement removal, relocation, and acquisition. Nonphysical nonstructural measures do not modify individual structures, but rather focus on behaviors and plans that reduce flood risk. They include evacuation plans, flood warning systems, flood insurance, floodplain mapping, emergency preparedness plans, risk communication, and land use regulations and zoning.

The nonstructural measures considered in this study are presented in **Table A-12**. Each measure was also screened to determine its applicability in the study area and the results of the screening are also presented in **Table A-12.**

Table A-12: Screening of Nonstructural Measures

Measure	Description	Carried Forward?	Discussion
Building Elevation (Raising)	Elevation involves raising the lowest finished floor of a building to a height that is above the flood level. This nonstructural technique lifts an existing structure to limit floodwaters from reaching living areas.	No	Structures in the study area are a mix of single-story industrial type buildings and multi-story commercial, institutional, and residential. Elevating these types of existing structures was judged by the PDT as not likely to be cost effective or feasible without substantial reconstruction of the existing asset.
Relocation	Relocation involves moving people or structures out of the floodplain. USACE policy requires that relocation recommendations become mandatory and include the potential use of condemnation if necessary.	Yes	The urban environment of the study area is heavily built out, such that relocation of structures within CCSF was judged as not likely to be cost effective, when compared to other physical NS measures. However, relocation of infrastructure systems is expected to be required to provide critical services such as wastewater management and transportation.
Acquisition (Buyout)	Acquisition involves purchase and elimination of flood damageable structures, allowing for inhabitants to relocate to locations away from flood hazards. Lands can then be preserved for open space, recreation, or other uses. USACE policy requires that acquisition recommendations become mandatory and include the potential use of condemnation if necessary.	Yes	Through a manage retreat approach, acquisition of assets is expected and utilized.
Dry Floodproofing	Dry floodproofing includes a range of strategies that seal the exterior of a building from flood waters and is often used to protect non-residential structures, water supplies, and sewage systems. For example, a measure could include applying a waterproof veneer to the outside surface of an existing structures. Backflow valves could be installed on sewer lines to prevent back up during flooding and storm events (FEMA n.d.). At building openings, deployable gates and shields can be activated during flood events to prevent flood damage to the building interior, while allowing continued use at other times.	Yes	USACE policy guidance advises against the use of dry floodproofing for residential structures, but this measure can apply to commercial, industrial, or institutional type structures.

Measure	Description	Carried Forward?	Discussion
Ring Walls	Ringwalls are floodwalls or levees constructed to encircle individual structures or small groups of structures. Ringwalls typically surround the entire building or property with a limited number of access points. They are subject to the same design standards as floodwalls.	Yes	These are judged as a reasonable asset level protection that is suited to the dense urban environment whose structures were built out without the anticipation of structure raising, dry or wet floodproofing.
Wet Floodproofing	Wet floodproofing allows floodwater to enter the structure, vulnerable items such as utilities appliances and furnaces are relocated or waterproofed to higher locations. By allowing floodwater to enter the structure hydrostatic forces on the inside and outside of the structure can be equalized reducing the risk of structural damage.	Yes	Wet floodproofing is identified for structure types that can accommodate loss of a first floor by transitioning it from living space to storage or parking space. The cost of wet floodproofing will include additional scope to offset the loss of living space and allow for construction of alternate accommodations.
Flood Warning Systems	A flood warning system is a communication pathway that can afford residents advance warning of flooding and allow them time to make appropriate preparations. While a flood warning system does not prevent flooding and does not reduce damage to property that is left in the path of floodwaters, it can provide an aid in reducing property loss and increasing the safety of individuals.	No	Warning systems are beneficial as an accompanying measure to the physical actions but judged to be insufficient to meet the objective of Alternative B.
Flood Insurance	Flood insurance provides financial benefits for property owners who hold policies. Insurance can be used to offset economic losses due to coastal storm damage.	No	Flood insurance is a policy tool that would aid in recovery but judged to be insufficient to meet the objective of Alternative B. Additionally, the nature of the RSLC coastal flooding will increase the frequency of damaging events such that insurance providers are unlikely to tolerate the high certainty of claims.
Floodplain Mapping	Floodplain mapping consists of using maps to communicate flood risk. Flood maps are typically generated using hydraulic and hydrodynamic models.	No	Flood mapping has been completed for the study area, but deemed insufficient to meet the objective of Alternative B to reduce physical damage.

Measure	Description	Carried Forward?	Discussion
Flood Emergency Preparedness Plan	Emergency preparedness plans are guides that include information about how to prepare for emergencies such as a coastal storm.	No	Flood emergency preparedness planning is beneficial as an accompanying measure to the physical actions but judged to be insufficient to meet the objective of Alternative B to reduce physical damage.
Land Use Regulations and Zoning	Through proper land use regulation, floodplains can be managed to ensure that their use is compatible with the severity of the flood hazard. Several means of regulation are available, including zoning ordinances, subdivision regulations, and building and housing codes. Their purpose is to reduce losses by controlling the future use of floodplain lands and would not be effective in mitigating the existing hazard.	No	Land use regulation is a policy tool that will influence development of new structures within the floodplain but deemed insufficient to meet the objective of Alternative B to reduce physical damage to existing assets. This nonphysical measure is related to the acquisition (physical) measure, which is used within the formulation of Alternative B. Zoning is a policy tool that will influence development of new structures within the floodplain but deemed insufficient to meet the objective of Alternative B to reduce physical damage to existing assets. This nonphysical measure is related to the acquisition (physical) measure, which is used within the formulation of Alternative B.
Evacuation Plans	Evacuation plans are guides that outline when and how residents will evacuate prior to an emergency	No	Evacuation planning is beneficial as an accompanying measure to the physical actions but judged to be insufficient to meet the objective of Alternative B to reduce physical damage.
Risk Communication	Risk communication is the exchange of information between experts and people who face a hazard such as a coastal storm.	No	Risk communication is beneficial as an accompanying measure to the physical actions but judged to be insufficient to meet the objective of Alternative B to reduce physical damage.

Notes:
Green means retained for further evaluation.
Yellow means tentatively retained for further evaluation in future stages of planning and design but not currently included in the alternatives.
Red means screened out.

A-6.3 Natural and Nature-Based Features and the Engineering with Nature Philosophy

EWN is the intentional alignment of natural and engineering processes to address flooding hazards while also delivering economic, environmental, and social benefits (*Appendix I: Engineering with Nature*). NNBFs refer to the landscape features used to reduce flood risk while restoring natural processes and providing ecosystem benefits. NNBFs may also produce other economic, environmental, and social benefits known as NNBF co-benefits. These landscape features may be natural (produced purely by natural processes) or nature-based (produced by a combination of natural processes and human engineering) and include such features as beaches, dunes, wetlands, reefs, and islands. Landscape features can be used alone, in combination with each other, and in combination with conventional engineering measures such as levees, floodwalls, and other structures (USACE 2021b). Within this document, the term “EWN” refers to the philosophy, whereas the term “NNBF” refers to the natural and nature-based feature, measure, or action. NNBFs can be combined across a terrestrial to aquatic transect to provide multiple *integrated* benefits in one location. The performance of these other benefits enhance coastal flood risk management performance.

The NNBFs considered in this study are presented in **Table A-13**. Each measure was also screened to determine its applicability in the study area and the results of the screening are also presented in **Table A-13.**

Table A-13: Screening of Natural and Nature-Based Features

Measure	Definition and Description	Carried Forward?	Notes
Enhancement of Existing Wetlands	Restoration or enhancement of existing coastal tidal wetlands, including establishment of inland migration corridor to maintain wetland area as sea levels rise.	Yes	• Enhanced coastal flood risk management benefits, increasing wave energy dissipation potential of coastal flood defense. • Likely efficient due to low relative cost relative to long-term benefits; areas for wetland enhancement along the shoreline are limited, although the number of species benefiting are numerous. • Acceptable and in line with local priorities and policies.
Wetland Creation	Establishment of a new coastal tidal wetland. This feature is primarily located along POSF lands in areas of retreat, requiring de-paving and infrastructure removal.	Yes	• Enhanced coastal flood risk management benefits, increasing wave energy dissipation potential of coastal flood defense, and relocation of at-risk structures out of the coastal floodplain. • Efficient at reducing long-term flood risk, although de-paving and removal of structures and infrastructure can be costly. • Acceptable and in line with local priorities and policies; however, relocation and land use changes for areas with active urban use may not have broad public support.
Ecotone Levee	Gently sloped habitat gradient that connect flood risk management levees to tidal marsh. They can provide transition zone habitat, which is important for high-water refuge and habitat connectivity, and attenuate waves to reduce levee erosion.	Yes	• Enhanced coastal flood risk management benefits, increasing wave energy dissipation potential of coastal flood defense. • Acceptable and in line with local priorities and policies. • Limited locations where ecotone levees can be established along the shoreline.

Measure	Definition and Description	Carried Forward?	Notes
Coarse Beach	Coarse sediment (cobble, gravel, larger rock size) beach acting as a submerged breakwater and wave energy dissipation feature. Includes both establishment and nourishment of coarse beach, located on the landward side of a sill or submerged dike parallel to the shore. Location adjacent to the store would not create a navigation hazard.	Yes	• Enhanced coastal flood risk management benefits, increasing wave energy dissipation potential of coastal flood defense. • Efficiency depends largely on technical cost considerations. • Acceptable and in line with local priorities and policies, particularly for recreation benefits and shoreline access. • Limited locations where a coarse beach can be established along the shoreline.
Living Seawall and Vertical Enhancements	Structural elements either integrated into seawalls or attached to seawalls (as panels) that create relief and varied microhabitat conditions. Living seawall elements can include a variety of structural elements that create shallow water habitat. This includes habitat benches or stair-cased shorelines, which are often found at the base of seawalls.	Yes	• Enhances coastal flood risk management benefits by providing additional wave energy dissipation potential. • Provides habitat value and may provide enhanced endangered species foraging habitat. • Public engagement by POSF has drawn broad public and agency support for this feature. • Acceptable and in line with local priorities and policies.
Naturalized or Embankment Shoreline	Naturalized or embankment shorelines can be planted with native vegetation to increase wave energy dissipation potential, reduce erosion risks, and provide tidal habitats and upland refugia.	Yes	• Provide similar coastal flood risk management benefits to traditional earthen levees. • Reduces O&M needs by reducing erosion potential, particularly during smaller more frequent storm events. However, may require managing invasive species. • Provide additional habitat, improved aesthetic, and community co-benefits.

Measure	Definition and Description	Carried Forward?	Notes
Ecological Armoring	Armoring units or materials that either replace traditional riprap (ecological and green riprap), integrate vegetation, or include enhancing features (such as tidepool units).	Yes	• Provide similar coastal flood risk management benefits to traditional gray armoring measures (riprap). • Provides additional habitat, improved aesthetic, and community co-benefits.
Creek Enhancements	Improvements to the existing creek banks (beyond raising the shoreline elevation to provide coastal flood risk management benefits). Can range in scale and include habitat shelves, planted edges, live crib walls, and other measures that increase surface complexity.	Yes	• Required NNBF for the success of other flood risk reduction measures. • Enhancements would provide erosion control and stabilization tidal creek banks. • Creek bank improvements may improve water quality, although these benefits are uncertain. • Habitat and community benefits depend on the feature selected for implementation.
Green Stormwater Infrastructure (GSI)	Features that address urban stormwater by slowing, capturing, and infiltrating runoff. Includes green streets, tree trenches, bioswales, green roofs, and other features.	Yes	• Required NNBF for the success of other flood risk reduction measures. • SLR and elevated Bay water levels will increase inland stormwater flood risks due to insufficient stormwater drainage capacity. • Raised shoreline structures associated with the alternatives will disrupt direct inland runoff to the Bay and increase inland stormwater flood risks. • GSI features that reduce stormwater runoff can provide habitat value, minimize heat islands, and provide other benefits.
Mudflat Augmentation	Consolidated fine-grained sediment deposits.	Tentatively Yes	• Tentatively retained as part of a combination measure. Included as a supplemental component of wetland restoration and establishment.

Measure	Definition and Description	Carried Forward?	Notes
Pier and Piling Habitat Improvement	Replacing creosote piles, paneling, and texturing of piles (e.g., pile wraps), as well as substrate improvements.	Tentatively Yes	• May provide wave energy dissipation underneath piers; insufficient information available to assess coastal flood risk management potential. • Provides similar habitat benefits as the living seawall feature; greater benefits could result if pier and piling habitat improvements are coupled with adjacent living seawall features.
Subtidal Habitat Improvements	Establishment of beds of underwater flowering plants/submerged aquatic vegetation. Creation of shellfish and oyster beds along the shallow Bay floor. Creation of artificial/constructed reef structures constructed from a variety of materials, ranging from rock to oyster shells, from concrete structures to prefabricated modules and products.	Tentatively Yes	• Not included as an independent measure; where this feature is appropriate along the San Francisco shoreline, it requires other adjacent features for wave attenuation benefits (e.g., oyster reefs paired with eelgrass beds). • Tentatively retained as part of a combination measure. Included as a supplemental component of wetland restoration and establishment (e.g., constructed oyster reefs can help reduce marsh edge erosion). • Could be integrated into embankment or naturalized/embankment shoreline designs to provide toe protection along nearshore environment.

Measure	Definition and Description	Carried Forward?	Notes
Living Breakwater (new or enhanced)	Offshore vertical breakwater structure parallel to the shore with a variety of ecosystem-enhancing features.	Tentatively Yes	• Breakwaters and breakwaters improvements were not considered as part of the alternatives, but they can provide coastal flood risk management benefits. • Ecosystem enhancements could be added to existing breakwaters to provide habitat benefits. • A new offshore vertical breakwater can support ecosystem-enhancing features while reducing wave energy, reducing the height of the coastal flood defenses. • A traditional rock breakwater is likely infeasible given the deepwater along the San Francisco shoreline. • This feature was retained for additional study given potential coastal flood risk management benefits and applicability to study area.
Afforestation and Urban Corridors	Extensive tree planting focusing on areas with extensive nonpermeable surfaces and stormwater runoff.	Tentatively Yes	• This feature does not address the primary study authority of addressing coastal flood risk management benefits. • May provide inland stormwater drainage benefits and reduce inland stormwater flood risk. • Supports other benefits, including reducing heat islands and improving community well-being.
Submerged Breakwater	Offshore structures parallel to the shore; can be constructed of varied materials, from rock, oyster shell, to artificial reef structures. The highest elevation of the structure is intended to be submerged for some or all the tidal cycle.	No	• This feature could pose a navigation hazard within the study area. • The Bay’s large tidal range limits the effectiveness of submerged features for reducing wave energy.

Measure	Definition and Description	Carried Forward?	Notes
Sandy Beaches (establishment and nourishment)	Fine-sediment (sandy) beach acting as a submerged breakwater and flood protection. Includes creation of a sandy beach on the landward side of a sill or submerged dike parallel to the shore.	No	• Sandy beaches are not efficient in this highly constrained and diversified shoreline. • Erosion concerns for sandy sediments. • Operations and maintenance costs are likely cost prohibitive, making this feature inefficient at providing coastal flood risk management benefits.
Polder Creation	Low-lying area enclosed by dikes and disconnected from surrounding hydrology.	No	• Insufficient area to create polders along the San Francisco shoreline. • Existing restoration efforts in the Bay are focused on restoring tidal action to polders to create tidal wetlands. Creation of new polders would be in opposition of this restoration goal.
Islands	Constructed or restored barrier, deltaic or in-Bay islands.	No	• Not appropriate for the deep water setting along much of San Francisco's shoreline. Additional challenges include: ▪ Permitting ▪ Local acceptability ▪ Cost ▪ Feasibility
Creek Daylighting	Restoration of waterways that have been covered, piped, or canalized to a naturalized, aboveground condition. Creek daylighting could include restoration of adjacent floodplains with embankments to contain creek flows during high flow events.	No	• This feature does not address the primary study authority of addressing coastal flood risk management benefits. • This feature could potentially be part of a GSI plan to address inland stormwater issues. • This feature may be cost prohibitive in the densely urbanized watersheds of San Francisco.

Measure	Definition and Description	Carried Forward?	Notes
Watershed and Creek to Baylands Reconnection	Restoration of Bay hydrological system across the transect using dam removal, upstream creek restoration, and creek mouth delta restoration.	No	• Similar to creek daylighting, although larger in scale; could require restoration of historic creek mouth/deltas. • Restoration of this scale in a densely urbanized city would be cost prohibitive. • Restoration of this scale would require substantial retreat, including relocation of homes, businesses, and transportation corridors.
Wharf Enhancements (Light Penetration)	Penetrations and wells in wharf structures to allow light to penetrate the water columns under the wharf.	No	• Light penetrating features provide enhanced photosynthesis opportunities for species; the water in the vicinity of the seawall is relatively clear. • The Bay water adjacent to San Francisco's seawall is extremely turbid, blocking light penetration of any significant depth below the water surface; this feature is unlikely to provide much benefit within the study area.

Notes:
Green means retained for further evaluation.
Yellow means tentatively retained for further evaluation in future stages of planning and design but not currently included in the alternatives.
Red means screened out.

Section A-7. Focused Array of Alternative Plans

The measures that were screened and retained were used to develop a focused array of alternative plans consistent with the broad conceptual approaches of defend, accommodate, retreat, and hybrid; identify a phased adaptation approach; and incorporate NNBFs, as appropriate or possible.

Consistent with study guidance, the alternative plans were evaluated under three USACE RSLC scenarios. Coastal flood events have little variation in water surface elevation from small to extreme events, thus flood risk is primarily driven by RSLC in combination with coastal storms. As described earlier, the variation of scale and type of actions across alternatives was a strategic approach to assess the difference in performance under uncertain timing of RSLC. The economic analysis supported assessing the cost effectiveness of the risks of over- or under-building flood risk management features under each RSLC scenario. The resulting alternatives are:

Alternative A No Action

Alternative B Nonstructural

Alternatives C and D

Alternative C Defend, Scaled for Lower Risk

Alternative D Defend, Scaled for Low-Moderate Risk

Alternatives E, F, and G

Alternative E Defend Existing Shoreline, Scaled for Higher Risk

Alternative F Manage the Water, Scaled for Higher Risk

Alternative G Partial Retreat, Scaled for Higher Risk

Alternatives D, E, F, and G were all designed to be adaptive, with a second action occurring in 2090. This second action both increased the finish elevation of the structural measure, thereby providing a higher level of risk management, but also, in some cases, changed the alignment. The 2090 alignments were designed either to defend the shoreline (Alternative E), manage the water (Alternative F), or partially retreat from high-risk areas (Alternative G).

The alternatives were formulated to include a range of NNBFs that can dissipate wave energy and provide coastal storm risk reduction benefits (Appendix I: Engineering with Nature). Although additional NNBFs can support mitigation; these NNBFs have not been included in the alternatives.

The PDT identified representative scales of RSLC as building blocks of 1.5 feet, 3.5 feet, and 7 feet of SLC and are depicted in **Table A-14**.

Table A-14: Sea Level Change Performance by Alternative

Alternative	2040 Target Performance	2040 Finish Elevation	2090 Target Performance	2090 Finish Elevation
Alternative A	**No Action**			
Alternative B	**Floodproof areas at risk of 1% AEP coastal flooding; retreat areas at risk of monthly coastal flooding; add assets as risk increases over time**			
Alternative C	**1.5’ SLC**	**13.5’ NAVD88**	**N/A**	**N/A**
Alternative D	**1.5’ SLC**	**13.5’ NAVD88**	**3.5’ SLC**	**15.5’ NAVD88**
Alternative E	**3.5’ SLC**	**15.5’ NAVD88**	**7.0’ SLC**	**19.0’ NAVD88**
Alternative F	**3.5’ SLC**	**15.5’ NAVD88**	**7.0’ SLC**	**19.0’ NAVD88**
Alternative G	**3.5’ SLC**	**15.5’ NAVD88**	**7.0’ SLC**	**19.0’ NAVD88**

A-7.1 Alternative A: No Action (FWOP Condition)

Alternative A is the “No Action” alternative, meaning no action is taken by USACE to reduce flood risks beyond projects that have already been implemented or are approved for implementation along the San Francisco waterfront as described in the FWOP condition. Alternative A represents a baseline for comparison to evaluate the costs and benefits of all other alternatives and is the same as the FWOP condition described in **Section A-4.1.3**. Taking no action would not reduce the risk of coastal flooding that could begin to cause economic damages and interruptions to private property and public assets and impact transportation corridors, the performance of the wastewater and stormwater system, and the stability of the electrical grid. Many areas of the shoreline would be overtopped by frequent “high tide flooding” in the absence of large storms. This would occur first in the winter months when King Tides could flood roadways, causing road and transit closures. In the long-term, low-lying areas would be subjected to more prolonged flooding, damage, and disruption. Eventually low-lying areas could be flooded daily by the rise and fall of the Bay tides. Over time, this is projected to result in lower quality of life, lowered property values, and the displacement of businesses, jobs, and homes.

Some public and private projects that are already underway or are planned would address SLR in those areas (such as Mission Rock and Pier 70 or Islais Creek/3rd Street Bridge), but these are targeted efforts that address a very small portion of a much larger problem. In some cases, these projects will effectively be stranded as islands if not tied into a broader plan to address SLR.

A-7.2 Alternative B: Nonstructural

Alternative B is a nonstructural plan that moves people and assets away from the flood risk. Nonstructural measures (such as floodproofing) reduce consequences of flooding and allow water to disperse naturally rather than constructing traditional structural solutions. In Alternative B, buildings and critical city systems could be floodproofed, relocated, or retreated from so that they are not damaged when flood waters enter the area.

As sea levels rise and flood risks change over time, areas of the city that could flood frequently may be good candidates for managed retreat where people and assets are moved out of risk areas to avoid recurring damage and disruption. Alternative B assumes that the Federally cost-shared plan will assist public and private owners to take proactive steps to minimize flood damage to their assets and properties such as floodproofing, modifying, or removing buildings and infrastructure to reduce the risk of flood damages as sea levels rise.

The extent of the infrequent and frequent flood zones will increase, such that floodproofing and managed retreat actions sweep inland over time. As many of these actions are occurring on an asset-by-asset basis, they are highly responsive to the expected SLR trajectory. To evaluate alternatives as part of the Final Array, there are two variants of the nonstructural alternative.

One variant (lower-risk scenario) follows the USACE intermediate curve trajectory of SLR and uses the associated flood zones to determine the cost, benefits and impacts to assess this plan, while the second variant (higher risk scenario) follows the USACE high curve trajectory, which implicates larger areas of the city at an earlier point in time. Following these two trajectories, proactive actions (floodproofing or retreat) based on expected flood frequency are proposed and quantified at 25-year increments resulting in four action steps to span the 100-year POA.

As a baseline assumption, buildings and critical city infrastructure within the infrequent flood zone are floodproofed to prevent physical damage but will incur periodic disruption of services whenever a potential coastal flood event is forecast, likely resulting in evacuation and business shutdown for hours to days. Areas within the frequent flood zone would be retreated from. This will require property buyout, asset condemnation, and removal of the built environment. This also presents an opportunity for this space to be re-imagined with nature-based features that would provide ecological habitat and associated benefits. Essential utilities, such as wastewater, water, and the electric grid would be relocated or modified to continue providing service for the inland areas of the city for both floodproofing and retreat scenarios. Major transportation and transit corridors would be permanently disrupted or require network reconfiguration to mitigate this disruption.

The basic assumptions that guide the nonstructural actions are:

- Assets that fall within the inundation zone for the 1% AEP coastal event will be dry-floodproofed for inundation depths less than 3 feet.
- Assets that fall within the inundation zone for the monthly coastal event will be acquired, demolished, and abandoned (i.e., retreat).
- Individual assets may be lumped within flood areas that do not meet the specified criteria to avoid isolated and stranded assets.

This alternative would only involve actions that reduce human exposure and vulnerability to flooding but does not attempt to change flows. In this alternative, the area of potential flooding would not be substantially changed. **Figure A-22** and **Figure A-23** visualize the floodproof and retreat zones across timesteps for the lower-risk scenario and higher risk scenario, respectively.

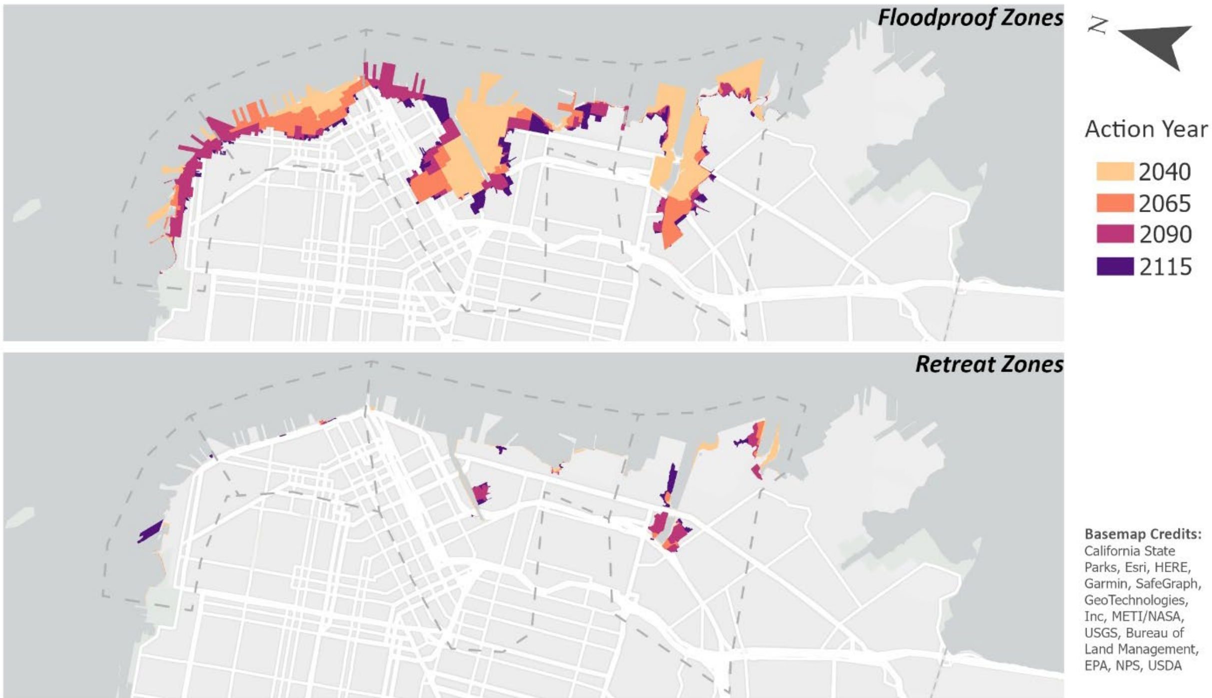


Figure A-22: Floodproof and Retreat by Time Step for Lower-Risk Scenario

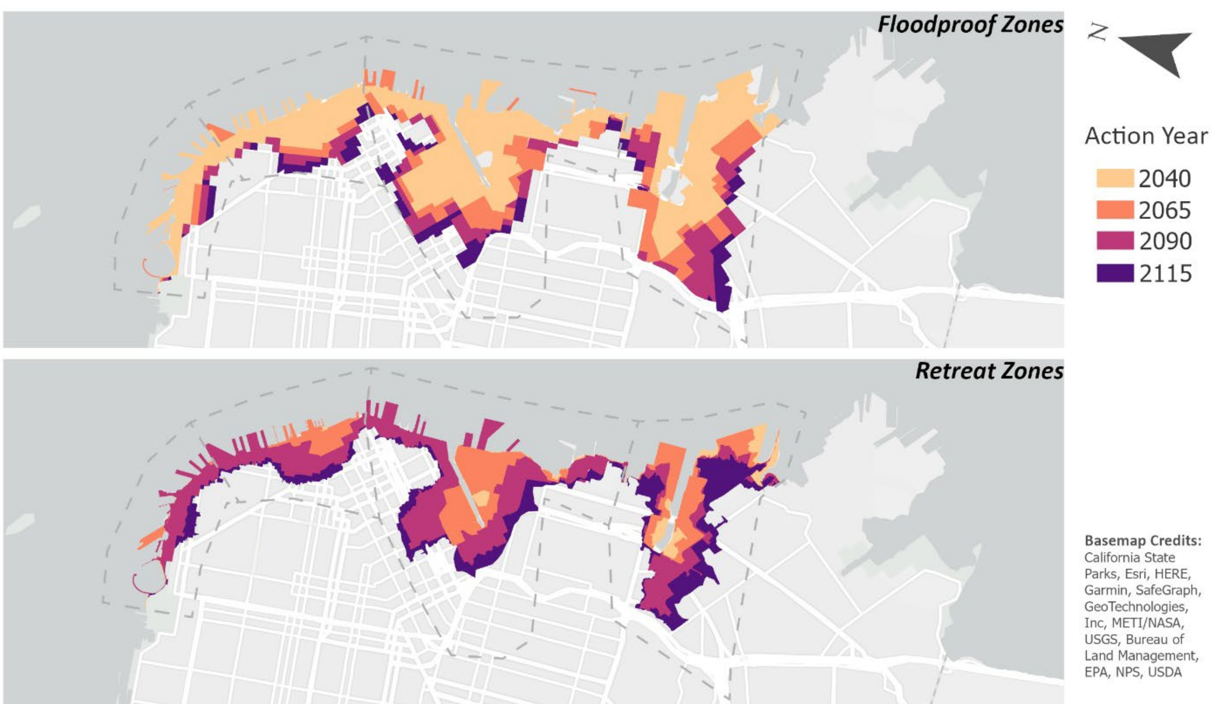


Figure A-23: Floodproof and Retreat by Time Step for Higher Risk Scenario

A-7.2.1 Floodproofing

Alternative B assumes a combination of dry floodproofing, elevation, wet floodproofing, and perimeter ring walls to reduce risk in the infrequent flood zone. The assumed floodproofing measure was determined based upon the frequency of use, structure value, and typical footprint (**Table A-15**).

Table A-15: Anticipated Floodproofing Measure Based on Structure Type

Structure Type	Floodproofing Measure
Industrial	Dry Floodproofing
Residential *Includes Residential, Single-Family Residential, Multi-Family Residential*	Elevation or Wet Floodproofing
Commercial and Other *Includes Commercial, Institutional, Mixed-Use, and Other*	Perimeter Ring Wall
Open Space and Vacant	None

A-7.2.2 Property Acquisition and Demolition

The proposed acquisition and demolition would serve to eliminate the risk to people and property. Acquisition for these properties would follow the same process of targeting willing sellers and properties in the higher frequency floodplains first. At this phase, it is uncertain whether the NFS would retain ownership of the land or turn it over to another entity. All acquired properties would have deed restrictions stating that no construction of any structure would be permitted. The ground after demolition would be prepared for regular flooding.

A-7.2.3 Scaling for Lower and Higher Risk

There are different numbers of structures and facilities that would be dry-floodproofed or acquired and demolished including single-family residential homes, multi-family residential homes, institutional, commercial, and industrial buildings, and city services such as transit corridors and wastewater facilities depending on the risk. The nonstructural plan was scaled for two levels of risk – a lower risk based on the USACE Intermediate RSLC scenario and a higher risk based on the USACE High RSLC scenario. Additionally, implementation of the nonstructural plan would be phased. The phased implementation would occur in 2040, 2065, 2090, and 2115. Actions include floodproofing or retreat (acquisition and demolition). **Table A-16** shows the number of structures by phase for the lower- risk scenario and **Table A-17** shows the number of structures by phase for the higher risk scenario.

Table A-16: Number of Structures by Time Step for Lower-Risk Scenario

Action	Measure(s)	2040	2065	2090	2115	Total
Floodproof	Dry Floodproofing	254	147	45	37	483
	Elevation/Wet Floodproofing	55	118	27	16	216
	Perimeter Ring Wall	204	173	164	80	621
Retreat	Acquisition, Demolition	16	14	32	21	83

Table A-17: Number of Structures by Time Step for Higher Risk Scenario

Action	Measure(s)	2040	2065	2090	2115	Total
Floodproof	Dry Floodproofing	617	272	289	267	1445
	Elevation/Wet Floodproofing	238	47	193	324	802
	Perimeter Ring Wall	567	217	342	262	1388
Retreat	Acquisition, Demolition	60	460	973	639	2132

Additionally, roadway and trackway routes will be floodproofed or at times be retreated (lost) due to the frequency of inundation, as shown for the lower-risk scenario (**Table A-18**) and the higher risk scenario (**Table A-19**).

Table A-18: Miles of Roadway and Trackway Floodproofed and Retreated for Each Time Step for Lower-Risk Scenario

Year	2040	2065	2090	2115
Roadway				
Floodproof	23.9	15.6	14.7	6.2
Retreat	0.3	0.2	1.7	0.8
Trackway				
Floodproof	17.0	3.8	5.9	0.8
Retreat	0.0	0.1	0.6	0.8

Table A-19: Miles of Roadway and Trackway Floodproofed and Retreated for Each Time Step for Higher Risk Scenario

Year	2040	2065	2090	2115
Roadway				
Floodproof	56.9	9.6	21.5	16.2
Retreat	2.5	21.7	33.7	11.5
Trackway				
Floodproof	36.2	4.8	2.2	0.4
Retreat	0.8	12.0	12.4	5.6

A-7.3 Alternative C: Defend, Scaled for Lower Risk

Alternative C is a structural alternative formulated to address lower rates of SLR, consistent with the USACE low and intermediate RSLC but may not be consistent with State of California and City of San Francisco SLR guidance unless it were incorporated within a more robust plan addressing higher rates of SLR. The design crest elevation for the measures in 2040 is 13.5 feet NAVD88.

To address the lower rates of SLR, Alternative C is engineered to reduce exposure of the shoreline to significant overtopping with 1.5 feet of SLR. The alternative is assumed to be a continuous line of protection with a crest elevation that was established to avoid overtopping caused by wave runup in addition to high water levels in the Bay. This alternative is largely composed of short walls and levees located near the edge of the existing shoreline. Some areas of the shoreline would include nature-based solutions and natural features that can reduce flood risks, while also enhancing Bay ecology and habitat. This alternative was developed without detailed consideration of local urban design standards, which may be addressed in future stages of design.

This alternative is distinct in that it is not envisioned to be easily adaptable to higher rates of SLR. For example, foundations would not be sized to support adding height at a future date. Where space is readily available, levees were selected due to lower cost. However, within the space-constrained urban right-of-way, floodwalls within the Embarcadero Promenade were identified as the most feasible measure. Additionally, the alternative includes short perimeter ring walls constructed along the apron of the existing finger piers to provide added protection from coastal storms and waves.

Foundations are constructed to meet the seismic performance requirements to ensure that higher water levels do not result in a high hazard to life safety during or following an earthquake, especially at the end of the study period when the coastal defenses routinely hold back Bay water.

The features of Alternative C by reach are described below. **Figure A-24** shows the alignment of the LOD.

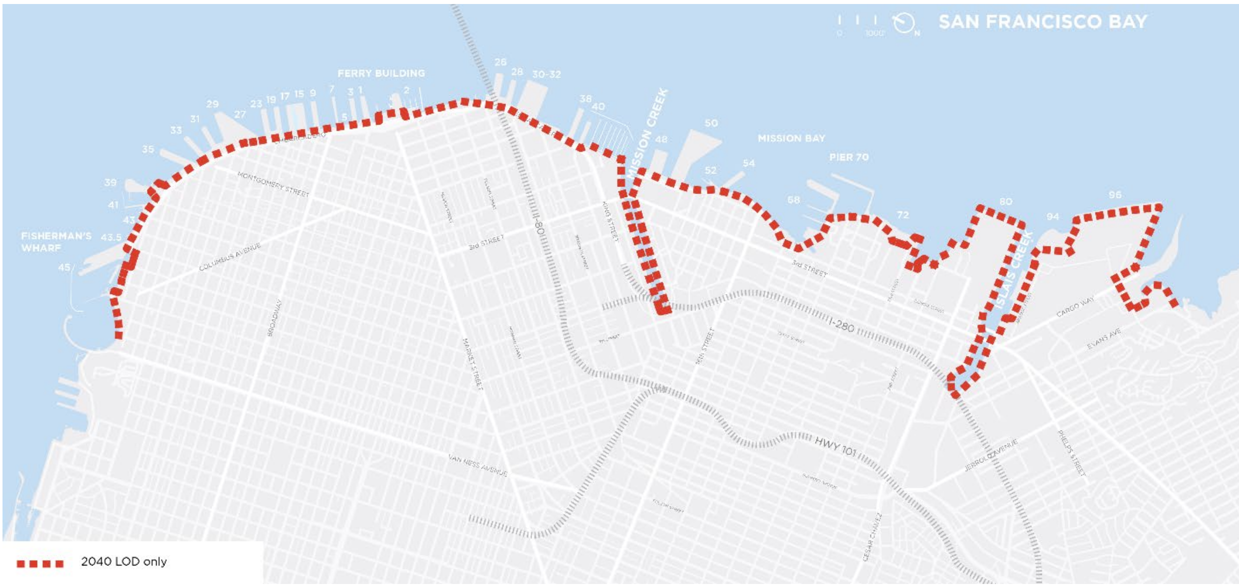


Figure A-24: Alternative C

A-7.3.1 Embarcadero (Reaches 1 and 2)

In the Embarcadero geography, Alternative C elevates the shoreline in place with floodwalls and levees, supported by a seismic foundation that extends into the roadway (**Figure A-25**). The actions in these reaches are described below:

- Use 1.5- to 4-foot-tall walls and levees within the Embarcadero Promenade to add coastal flood protection landward of the existing bulkhead wall.
- Perform ground improvement to reduce lateral spreading and liquefaction risk along the coastal flood defense alignment to ensure desired seismic performance.
- Construct 2-foot-tall concrete curb around perimeter of piers from Pier 47 to Pier 24.
- Install gates and deployable structures at key locations for vehicular and pedestrian access to piers and maritime facilities.
- Rebuild roadways along Little Embarcadero and Taylor Street between Powell and Jefferson Streets (adjacent to the Triangle parking lot).
- In Fisherman's Wharf, elevate or floodproof some buildings (<5), and consider demolition of buildings (<5) that straddle the coastal flood defense based on factors such as age and condition.
- Build infrastructure to manage stormwater. Coordinate with San Francisco Public Utilities Commission (SFPUC), San Francisco Public Works, and other stakeholders on changes to the combined sewer system, new pumps, green infrastructure, and other resilient building and street design opportunities and

other features to reduce inland flood risk exacerbated by the coastal flood defense structures.

Figure A-25: Alternative C, Embarcadero (Reaches 1 and 2)

A-7.3.2 Mission Creek/Mission Bay (Reach 3)

In the Mission Creek/Mission Bay geography, Alternative C defends existing city and community assets in place by elevating the creek and Bay shorelines with levees and floodwalls (**Figure A-26**). The coastal defense will tie into existing and planned high ground at Bayfront, Agua Vista and Crane Cove Parks, and at the Mission Rock and Pier 70 development areas. The actions in Reach 3 are described below:

- Use combination of 2.5- to 3.5-foot-tall walls and levees to raise creek and bayside shorelines, providing Bay Trail access atop or adjacent to bayside levees.
- Perform ground improvement to reduce lateral spreading and liquefaction risk along the coastal flood defense alignment to ensure desired seismic performance.
- Construct 2-foot-tall concrete curb around perimeter of piers from Pier 26 to Pier 50.
- Replace wharf at South Beach Harbor with new elevated wharf that ties into sloped fill back to existing ground.

- Install deployable closure structures at the northern and southern abutments of 3rd and 4th Street bridges over the creek to defend landward buildings and infrastructure from flood damage in the event of a coastal storm.
- Tie measures into existing and planned high ground at Bayfront, Agua Vista and Crane Cove Parks, and at the Mission Rock and Pier 70 development areas.
- Incorporate NNBFs into the shoreline along the north and south banks of Mission Creek.
- Floodproof some buildings bayside of the coastal flood defense along the Mission Bay shoreline (<10) and consider demolition of some buildings bayside of the defenses at Pier 68-70 (<5) based on factors such as age, condition, ground floor elevation, and historic status.
- Build infrastructure to manage stormwater. Coordinate with SFPUC, San Francisco Public Works, and other stakeholders on changes to the combined sewer system, new pumps, green infrastructure, and other resilient building and street design opportunities and other features to reduce inland flood risk exacerbated by the coastal flood defense structures.

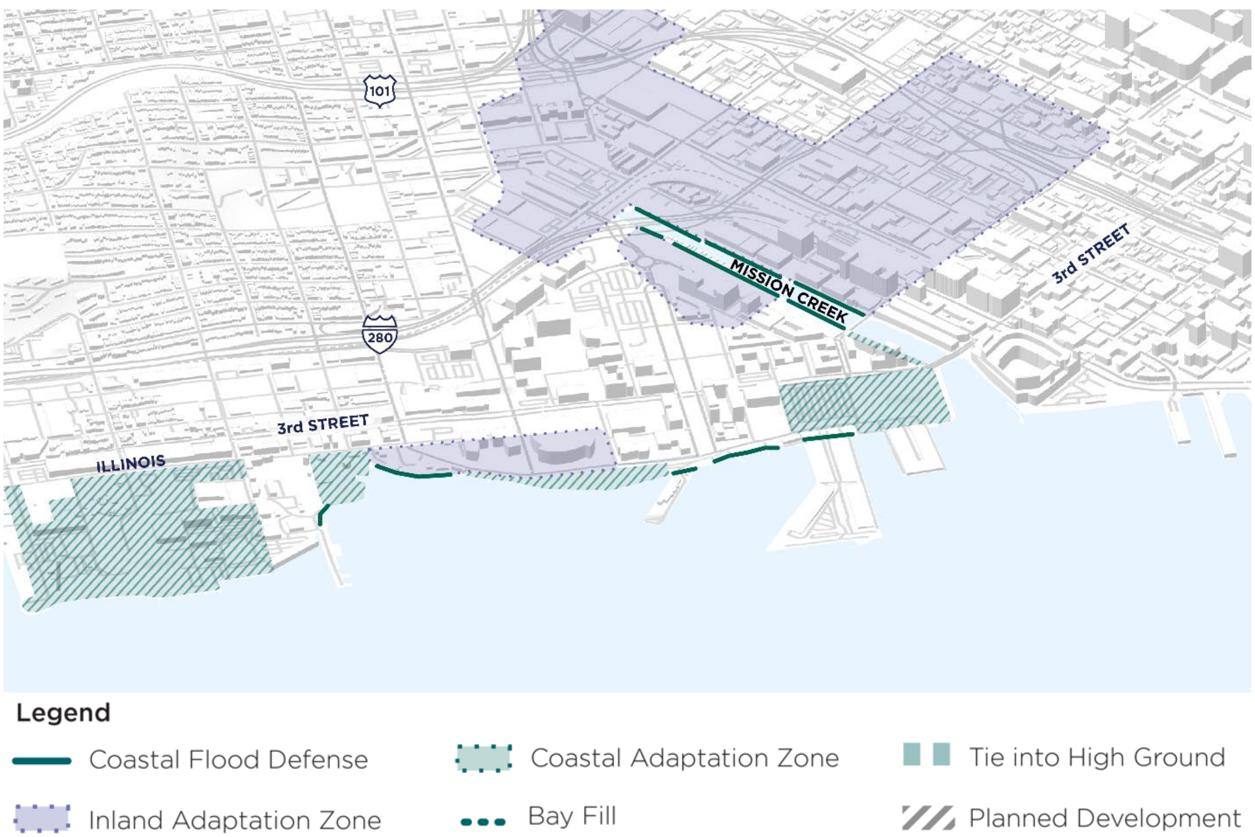


Figure A-26: Alternative C, Mission Creek/Mission Bay (Reach 3)

A-7.3.3 Islais Creek/Bayview (Reach 4)

In the Islais Creek/Bayview geography, Alternative C defends the existing shoreline to retain residential and commercial land uses in place, including POSF land uses and maritime facilities (**Figure A-27**). The flood defenses consist of raising the shoreline using levees, floodwalls, concrete curbs, deployable closure structures, and tying into existing or planned high ground near Potrero Power Station and behind the Pier 94 Wetlands (Port backlands). The actions in Reach 4 are described below:

- Use a combination of 3- to 4.5-foot-tall walls and levees to raise creek shorelines.
- Perform ground improvement to reduce lateral spreading and liquefaction risk along the coastal flood defense alignment to ensure desired seismic performance.
- Install concrete curb at edge of Pier 80 and levees and walls landward of P94-96 wharf intended to provide protection while maintaining function for maritime uses.
- Raise the Illinois Street Bridge and adjust connecting roads accordingly.
- The Third Street Bridge is currently being re-designed to defend against several feet of SLR (FWOP condition).
- Incorporate NNBFs into the shoreline along the southwest bank of Islais Creek and the Pier 94 Wetlands.
- Consider partial or full demolition of some buildings (<5) that straddle the coastal flood defense.
- Build infrastructure to manage stormwater. Coordinate with SFPUC, San Francisco Public Works, and other stakeholders on changes to the combined sewer system, new pumps, green infrastructure, and other resilient building and street design opportunities and other features to reduce inland flood risk exacerbated by the coastal flood defense structures.

Figure A-27: Alternative C, Islais Creek/Bayview (Reach 4)

A-7.4 Alternative D: Defend, Scaled for Low-Moderate Risk

Alternative D is designed to adapt the shoreline to withstand 1.5 feet of SLR, with the possibility of building higher (up to an additional 2 feet of SLR) closer to 2090 if SLR is projected to increase beyond the first line of protection. Alternative D addresses lower rates of SLR, consistent with the USACE low and intermediate RSLC curves but may not be consistent with State of California and City of San Francisco SLR guidance unless it was incorporated within a more robust plan addressing higher rates of SLR. The design crest elevation for the measures in 2040 is 13.5 feet NAVD88.

Alternative D is engineered to protect the shoreline from significant overtopping with 1.5 feet of SLR, while providing adaptability to SLR up to 3.5 feet. While 1.5 feet of SLR will only cause shoreline overtopping in discrete segments of the waterfront, the alternative is assumed to be a continuous line of protection with a crest elevation that was established to avoid overtopping caused by wave runup in addition to high water levels in the Bay.

This alternative proposes construction of short floodwalls and levees located near the edge of the existing shoreline and adding a 2-foot-high concrete curb around the perimeter of piers as an initial action in 2040. Some areas of the shoreline would include natural and nature-based features that can reduce flood risks, while also enhancing Bay ecology and habitat. This alternative was initially developed without detailed consideration of local urban design standards, which may be addressed in future stages of design. This alternative includes foundation elements that allow adaptation up to 3.5 feet of SLR.

Foundations would be constructed to meet the seismic performance requirements to ensure that higher water levels do not result in a high hazard to life safety during or following an earthquake, especially at the end of the study period when the coastal defenses routinely hold back Bay water.

A-7.4.1 2090 Adaptations to Alternative D

The 2040 structures are adaptable to perform under higher water levels as sea levels continue to rise. In most cases, the 2090 adaptative measure is the construction of a 2-foot-tall vertical extension wall added to levees and walls constructed in 2040. In 2090, this alternative includes reconstructing bulkhead wharves and buildings at a higher elevation to address 3.5 feet of SLR. New wharves will be constructed from Fisherman's Wharf to South Beach Harbor. The bridges over Mission Creek and the Illinois Street Bridge over Islais Creek would be raised with regrading of the vehicular and rail approaches to accommodate higher water levels while maintaining transportation connections across the creek.

The features of Alternative D by reach for both the 2040 initial construction and the 2090 adaptation are described below. **Figure A-28** shows the alignment of the LOD.

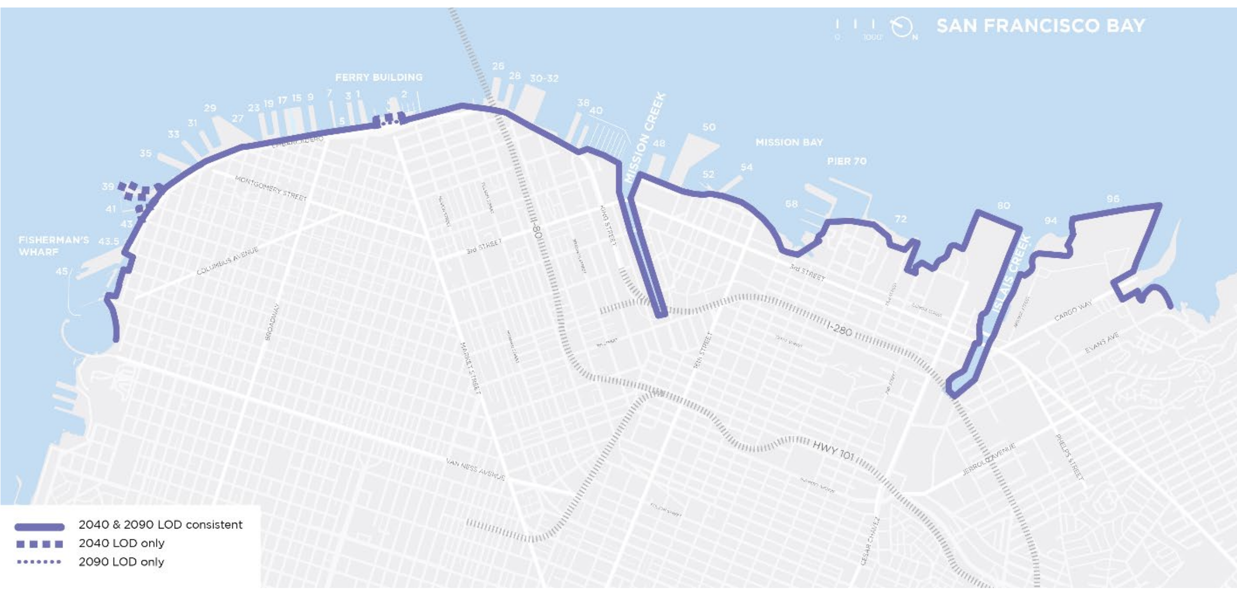


Figure A-28: Alternative D

A-7.4.2 Embarcadero (Reaches 1 and 2)

In the Embarcadero geography, Alternative D elevates the shoreline in place with floodwalls supported by a seismic foundation that extends into the roadway. In the subsequent action, wharves throughout the waterfront would be rebuilt at higher elevation.

Alternative D would include the following features by 2040 (**Figure A-29**):

- Use a combination of 2.5- to 4.5-foot-tall walls to raise Embarcadero Promenade landward of the existing bulkhead wall and wharves, except at the Ferry Building and Pier 39 where the LOD is a curb at the bayside perimeter of the piers and wharves.

- Build 1.5- to 4.5-foot-tall wall bayward of the Aquatic Park trail and Dolphin Club.
- Perform ground improvement to reduce lateral spreading and liquefaction risk along the coastal flood defense alignment to ensure desired seismic performance.
- Construct 2-foot-tall concrete curb around perimeter of piers from Pier 47 to Pier 24.
- Install gates and deployable structures at key locations for vehicular and pedestrian access to piers and maritime facilities.
- Rebuild roadways along Little Embarcadero and Taylor Street between Powell and Jefferson Streets (adjacent to the Triangle parking lot).
- Build infrastructure to manage stormwater. Coordinate with SFPUC, San Francisco Public Works, and other stakeholders on changes to the combined sewer system, new pumps, green infrastructure, and other resilient building and street design opportunities and other features to reduce inland flood risk exacerbated by the coastal flood defense structures.

Figure A-29: Alternative D, Embarcadero (Reaches 1 and 2) in 2040

Alternative D proposes the following actions for the 2090 adaptation (**Figure A-30**):

- Demolish the existing wharves and replace with elevated wharves to address 3.5 feet SLR. Wharves would meet the top of the stepped levee at landward side and slope up approximately 2 feet at bayward edge.
- Raise the Ferry Building and historic bulkhead buildings from Pier 24 to Pier 35.
- Where wharves are not reconstructed, add an additional 2 feet to levee crests and floodwalls.
- Build additional infrastructure to manage stormwater and reduce inland flood risk exacerbated by the coastal flood defense structures.

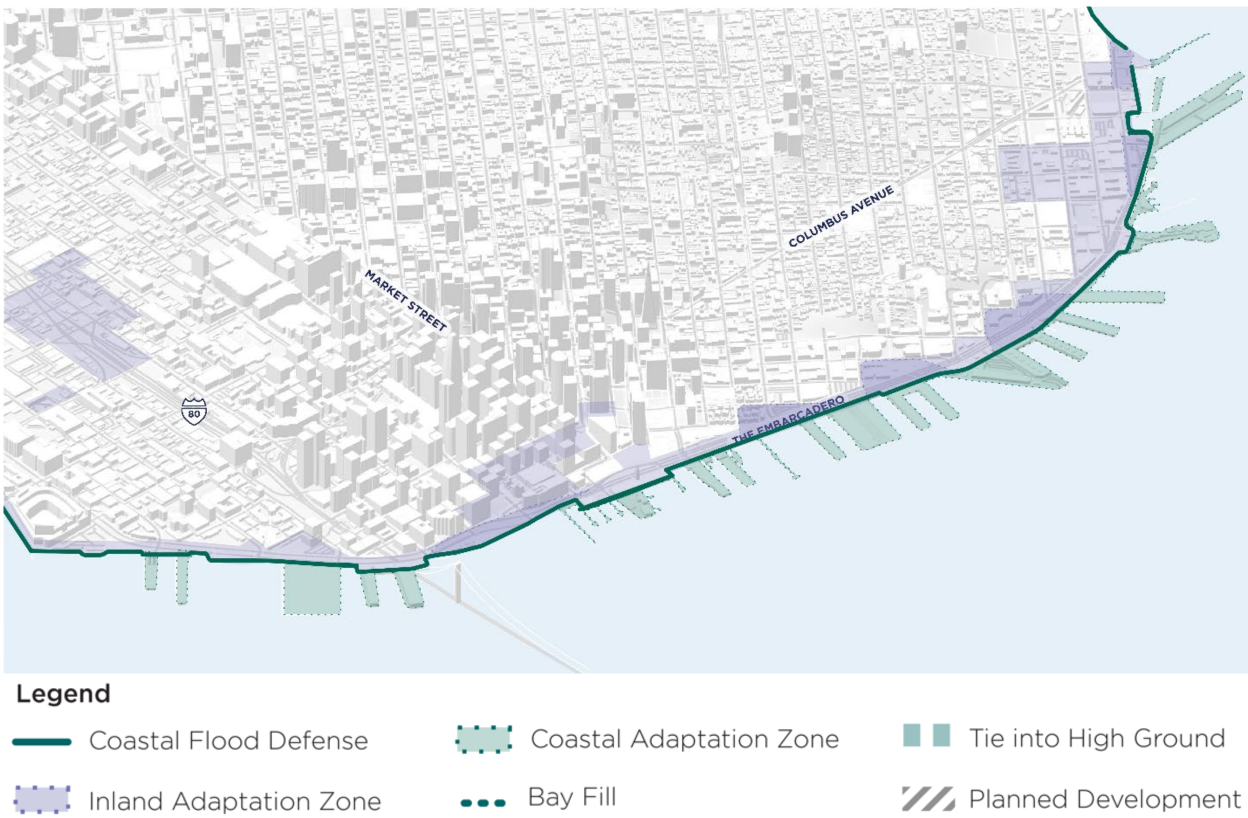


Figure A-30: Alternative D, Embarcadero (Reaches 1 and 2) in 2090

A-7.4.3 Mission Creek/Mission Bay (Reach 3)

In the Mission Creek/Mission Bay geography, Alternative D defends existing city and community assets in place by elevating the creek and Bay shorelines with levees and floodwalls, and, as a subsequent action, raised and rebuilt wharves. The coastal defense will tie into existing and planned high ground at Bayfront, Agua Vista and Crane Cove Parks, and at the Mission Rock and Pier 70 development areas.

Alternative D would include the following actions by 2040 (**Figure A-31**):

- Use a combination of 1.5- to 4.5-foot-tall walls and levees to raise the creek and bayside shorelines, providing Bay Trail access atop or adjacent to bayside levees.
- Perform ground improvement to reduce lateral spreading and liquefaction risk along the coastal flood defense alignment to ensure desired seismic performance.
- Construct 2-foot-tall concrete curb around perimeter of piers from Pier 26 to Pier 50.
- Raise and rebuild wharves at South Beach.
- Install deployable closure structures at the northern and southern abutments of 3rd and 4th Street bridges over the creek to defend landward buildings and infrastructure from flood damage in the event of a coastal storm.
- Tie measures into existing and planned high ground at Bayfront, Agua Vista, and Crane Cove Parks, and at the Mission Rock and Pier 70 development areas.
- Enhance wildlife habitat between Crane Cove Park and Pier 68 Shipyard using ENNBFs.
- Consider demolition of some buildings bayside of the defenses at Pier 68-70 (<5) based on factors such as age, condition, ground floor elevation, and historic status.
- Build infrastructure to manage stormwater. Coordinate with SFPUC, San Francisco Public Works, and other stakeholders on changes to the combined sewer system, new pumps, green infrastructure, and other resilient building and street design opportunities and other features to reduce inland flood risk exacerbated by the coastal flood defense structures.

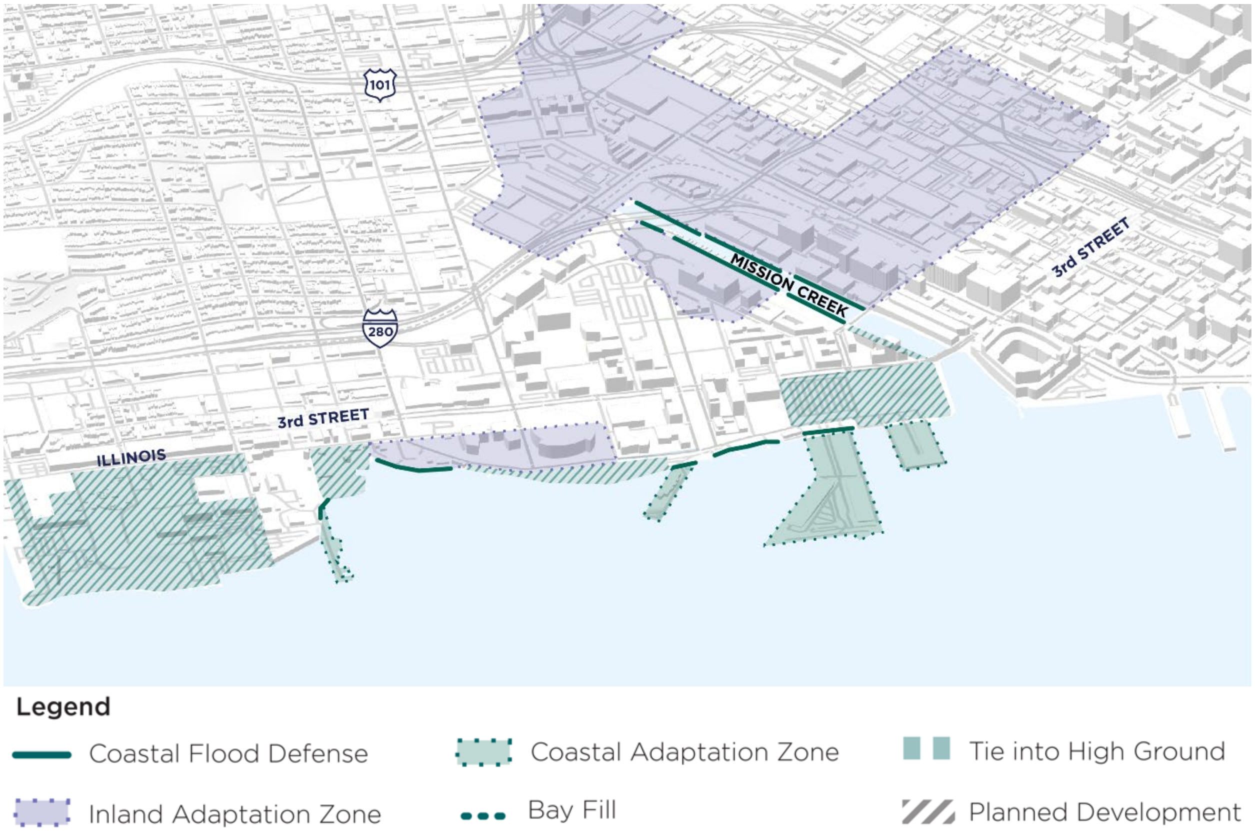


Figure A-31: Alternative D, Mission Creek/Mission Bay (Reach 3) in 2040

Alternative D would include the following actions for the 2090 adaptation (**Figure A-32**):

- Add an additional 2 feet to levees and walls constructed as part of 2040 scope.
- Demolish existing wharves from Bay Bridge to South Beach Harbor and replace with elevated wharves to address 3.5 feet SLR. Wharves would meet the top of the stepped levee at landward side and slope up approximately 2 feet at the bayward edge.
- Raise the historic bulkhead buildings from Pier 26 to Pier 40.
- Raise 3rd and 4th Street Bridges and regrade approaches.
- Maintain, enhance, or expand NNBFs between Crane Cove Park and Pier 68 Shipyard.
- Elevate select buildings bayside of the coastal flood defense along the Mission Bay shoreline (<5) and consider demolition of some buildings north of Crane Cove Park (<5) based on factors such as age, condition, and ground floor elevation.
- Build additional infrastructure to manage stormwater and reduce inland flood risk exacerbated by the coastal flood defense structures.

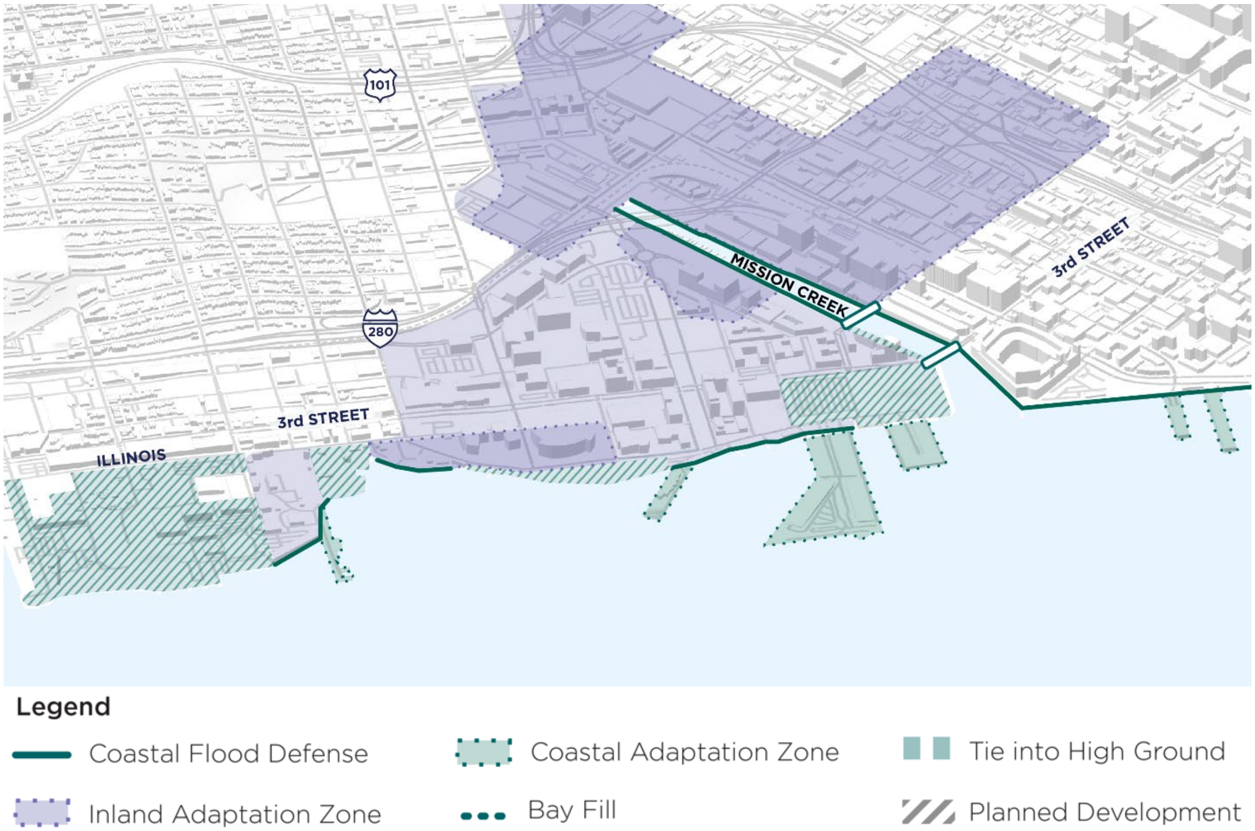


Figure A-32: Alternative D, Mission Creek/Mission Bay (Reach 3) in 2090

A-7.4.4 Islais Creek/Bayview (Reach 4)

In the Islais Creek/Bayview geography, Alternative D defends the existing shoreline to retain residential and commercial land uses in place, including POSF land uses and maritime facilities. The flood defenses consist of raising the shoreline using levees, floodwalls, concrete curbs, deployable and closure structures, and tying into existing or planned high ground near Potrero Power Station and behind the Pier 94 Wetlands (Port backlands).

Alternative D would include the following actions by 2040 (**Figure A-33**):

- Use a combination of 2.5- to 5.5-foot-tall walls and levees to raise creek shorelines.
- Construct a concrete curb at edge of Pier 80 and raise the edge of Pier 94-96 using levees and walls with openings to provide protection while maintaining function for maritime uses.
- Perform ground improvement to reduce lateral spreading and liquefaction risk along the coastal flood defense alignment to ensure desired seismic performance.

- Reconstruct Piers 90 and 92 wharves at higher elevation and incorporate into LOD.
- Incorporate NNBFs into the shoreline at Warm Water Cove, along the southwest bank of Islais Creek, and at the Pier 94 Wetlands.
- Install deployable closure structures at the northern and southern abutments of Illinois Street Bridge over the creek to defend landward buildings and infrastructure from flood damage in the event of a coastal storm.
- The Third Street Bridge is currently being re-designed to defend against several feet of SLR (FWOP condition).
- Consider partial or full demolition of some buildings (<5) that straddle the coastal flood defense.
- Build infrastructure to manage stormwater. Coordinate with SFPUC, San Francisco Public Works, and other stakeholders on changes to the combined sewer system, new pumps, green infrastructure, other resilient building and street design opportunities, and other features to reduce inland flood risk exacerbated by the coastal flood defense structures.

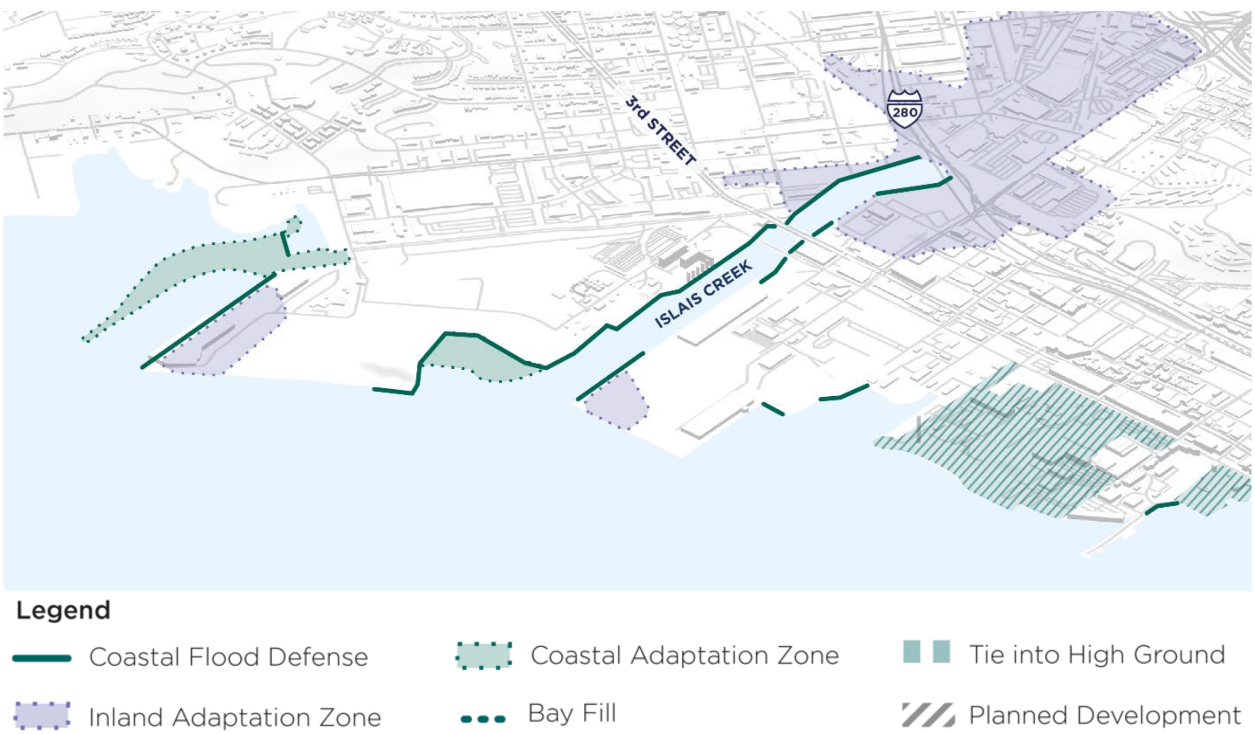


Figure A-33: Alternative D, Islais Creek/Bayview (Reach 4) in 2040

Alternative D would include the following actions for the 2090 adaptation (**Figure A-34**):

- Add an additional 2 feet to levees and walls constructed as part of 2040 scope.
- Raise Illinois Street Bridge and regrade approaches, likely resulting in the loss of freight rail access to Pier 80.
- Maintain, enhance, or expand NNBFs at Warm Water Cove, along the southwest bank of Islais Creek, and at the Pier 94 Wetlands.
- Consider demolition of some warehouse buildings (<5) at Warm Water Cove to make room for NNBFs.
- Build additional infrastructure to manage stormwater and reduce inland flood risk exacerbated by the coastal flood defense structures.

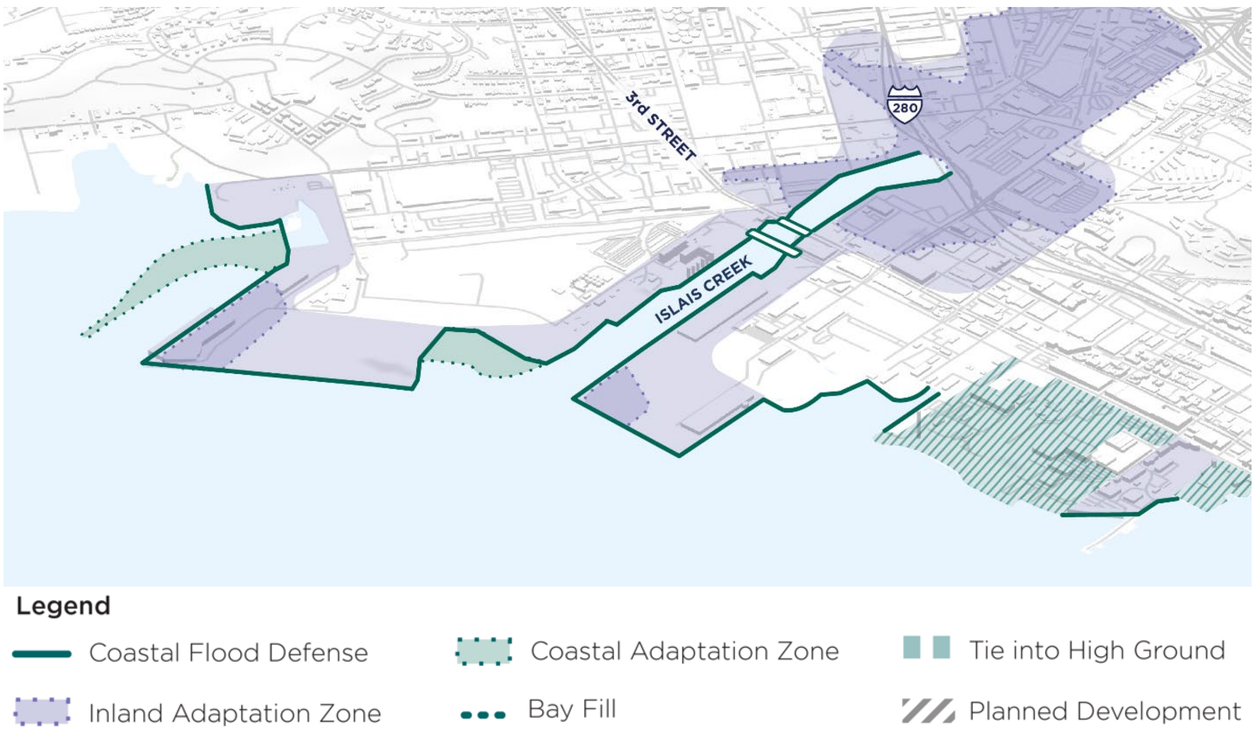


Figure A-34: Alternative D, Islais Creek/Bayview (Reach 4) in 2090

A-7.5 Alternative E: Defend Existing Shoreline, Scaled for Higher Risk

Alternative E is designed to adapt the shoreline to withstand 3.5 feet of SLR, with the possibility of building higher (up to an additional 3.5 feet of SLR) closer to 2090 if SLR is projected to increase beyond the first LOD. Alternative E addresses higher rates of SLR, consistent with the USACE high RSLC curve and is consistent with State of California and City of San Francisco SLR guidance. The design crest elevation for the measures in 2040 is 15.5 feet NAVD88.

Alternative E was designed to “hold the line” by preserving a waterfront that looks and functions much as it does today by adapting along the shoreline. Alternative E raises the shoreline using a combination of levees, seawalls, bulkhead wharves, and deployable closure structures. Where appropriate, the LOD ties into existing high ground. The shoreline is extended into the Bay along the Embarcadero and portions of Mission Bay to accommodate the new coastal flood defense structures to minimize disruption to key transportation facilities, emergency services, and other important city features.

Foundations are constructed to meet the seismic performance requirements to ensure that higher water levels do not result in a high hazard to life safety during or following an earthquake, especially at the end of the study period when the coastal defenses routinely hold back Bay water.

A-7.5.1 2090 Adaptations to Alternative E

The 2040 structures are adaptable to perform under higher water levels as sea levels continue to rise. The 2090 adaptations mostly include increasing the elevation of the 2040 measures, with one instance of extending the shoreline into the Bay at Rincon Park to provide additional space for the elevation gains required. The bridges over Mission Creek and the Illinois Street Bridge over Islais Creek would be raised with regrading of the vehicular and rail approaches to accommodate higher water levels while maintaining transportation connections across the creek.

The features of Alternative E by reach for both the 2040 initial construction and the 2090 adaptation are described below. **Figure A-35** shows the alignment of the LOD.

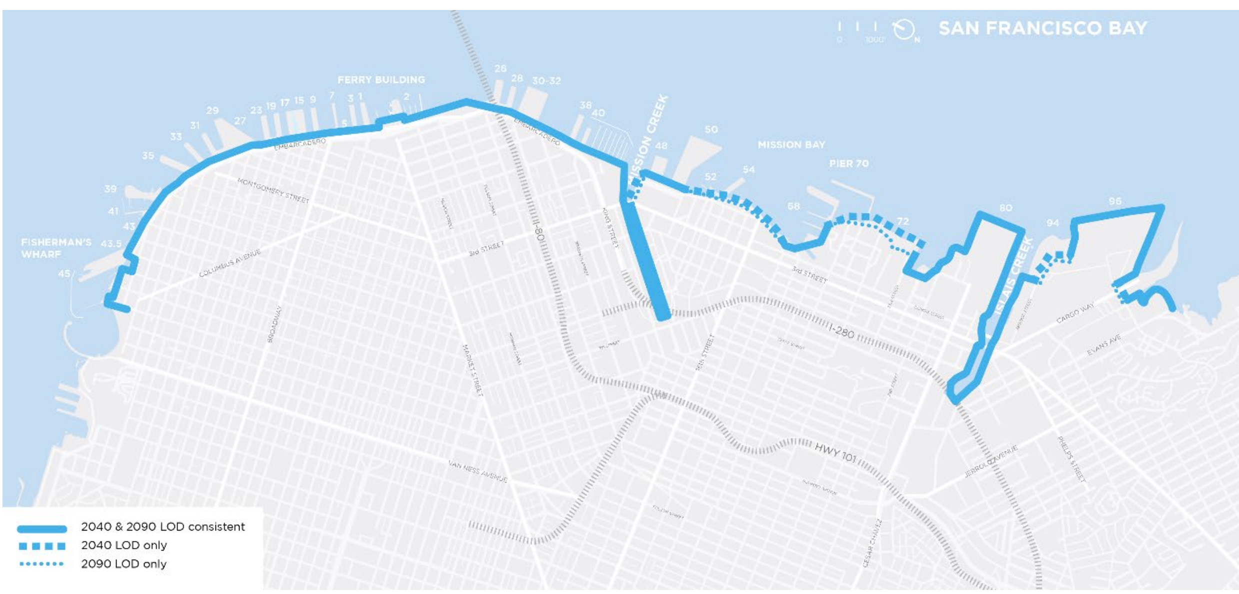


Figure A-35: Alternative E

A-7.5.2 Embarcadero (Reaches 1 and 2)

In the Embarcadero geography, Alternative E raises the shoreline using a bayward extension, aligning the new seawall approximately 20 feet bayward of the existing seawall. The extended shoreline includes a new integrated bulkhead wall and wharf.

Maintaining a wharf width of approximately 45 feet, the bulkhead buildings and wharf would be shifted bayward, reducing the overall length of the finger piers and historic sheds. To facilitate construction of this extended shoreline, a portion of each existing pier would be demolished during construction and rebuilt.

Alternative E would include the following actions by 2040 (**Figure A-36**):

- Extend the shoreline approximately 20 feet bayward of the existing seawall and elevate by 4 to 6 feet using raised and rebuilt bulkhead walls and wharves, and a levee along Hyde Street, to defend against 3.5 feet of SLR.
- Perform ground improvement to reduce lateral spreading and liquefaction risk along the coastal flood defense alignment to ensure desired seismic performance.
- Construct 2-foot-tall concrete curb around perimeter of piers from Pier 47 to Pier 24.
- Add modest amount of new Bay fill along Jefferson Street adjacent to the Inner Harbor between Jones and Taylor Streets.
- Reconstruct the northbound lanes and Muni light rail trackway along the Embarcadero roadway, including a generous Embarcadero Promenade and two-way bike lane for multi-modal use and recreation.
- Incorporate NNBFs into the bulkhead wall shoreline with textured vertical surfaces (living seawall) that serve a coastal flood risk management function by influencing wave runup, while also providing ecological functions.
- Elevate buildings (<20), including the Ferry Building and bulkhead buildings.
- Consider demolition of some buildings overlapping or adjacent to the construction area north of Jefferson Street and between Taylor and Hyde Streets (<20) based on factors such as age, condition, ground floor elevation, and historic status.
- Build infrastructure to manage stormwater. Coordinate with SFPUC, San Francisco Public Works, and other stakeholders on changes to the combined sewer system, new pumps, green infrastructure, other resilient building and street design opportunities, and other features to reduce inland flood risk exacerbated by the coastal flood defense structures.

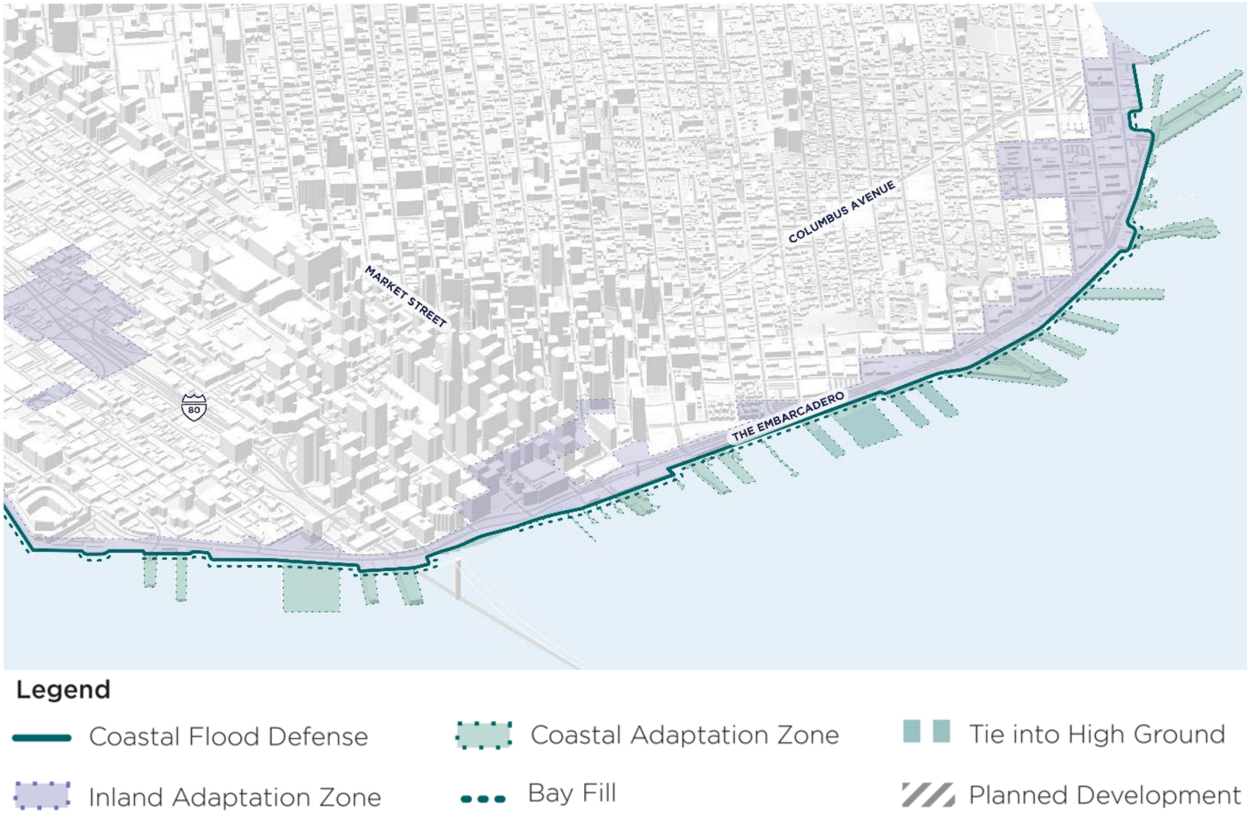


Figure A-36: Alternative E, Embarcadero (Reaches 1 and 2) in 2040

Alternative E would include the following actions for the 2090 adaptation (**Figure A-37**):

- Raise the shoreline by 3.5 feet by adding additional height to bulkhead walls and levee crests.
- At Rincon Park, extend the shoreline approximately 70 feet into the Bay and raise the shoreline to defend against 7 feet of SLR, while minimizing additional impact to the Embarcadero roadway. Includes construction of a new seawall, substantial Bay fill, and ground improvement.
- Raise and rebuild wharves at a higher elevation at the end of their assumed 50-year design life.

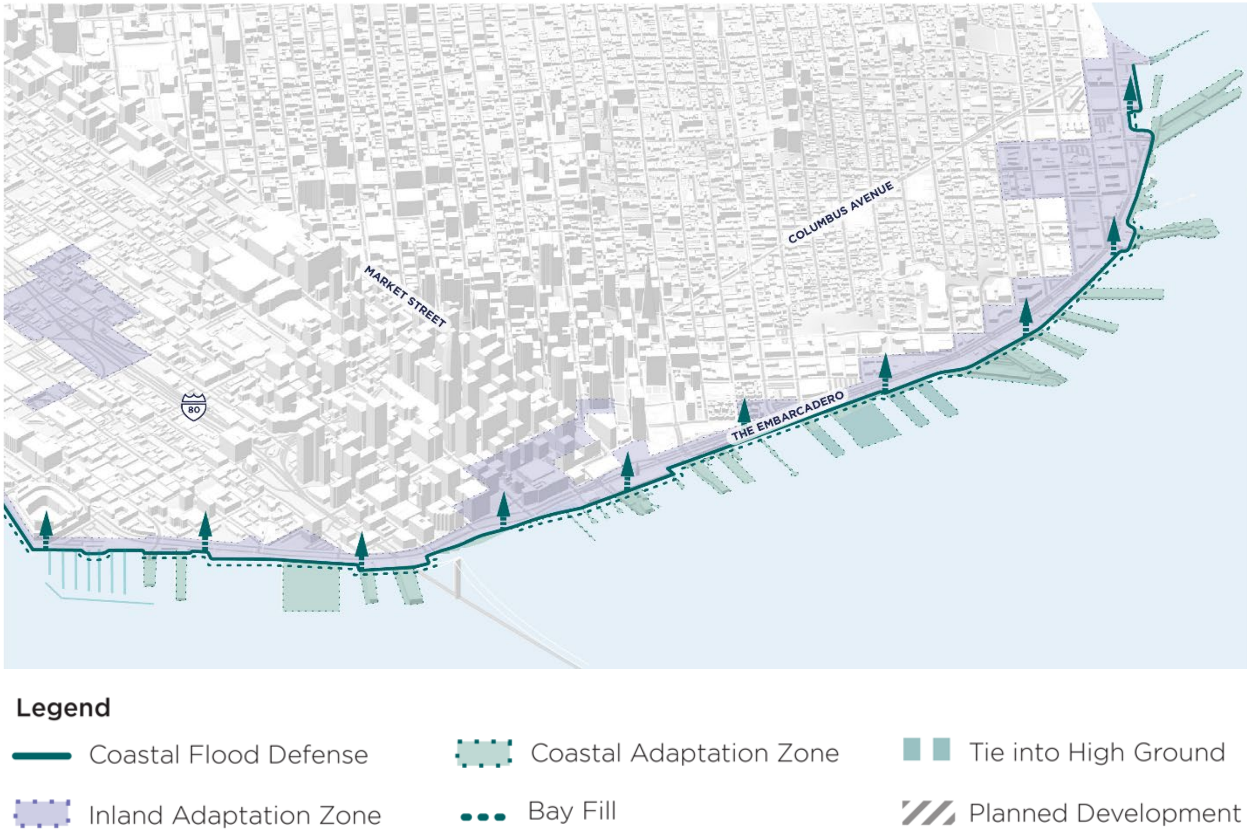


Figure A-37: Alternative E, Embarcadero (Reaches 1 and 2) in 2090

A-7.5.3 Mission Creek/Mission Bay (Reach 3)

In the Mission Creek/Mission Bay geography, Alternative E defends existing city and community assets in place by elevating the creek shoreline with a levee, extending parts of the cove and Bay shoreline bayward, installing deployable closure structures and later raising bridges, and tying into existing or planned high ground. This alternative requires some new Bay fill to balance impacts to the roadway along Terry Francois Boulevard while maintaining the necessary amount of space required to meet the flood defense elevation.

Alternative E would include the following actions by 2040 (**Figure A-38**):

- Elevate the Bay and creek shorelines by 3 to 6 feet using a combination of levees and raised bulkhead walls and wharves to defend against 3.5 feet of SLR.
- Perform ground improvement to reduce lateral spreading and liquefaction risk along the coastal flood defense alignment to ensure desired seismic performance.
- Construct 2-foot-tall concrete curb around perimeter of piers from Pier 26 to Pier 50.

- Install deployable closure structures at the northern and southern abutments of 3rd and 4th Street bridges over the creek to defend landward buildings and infrastructure from flood damage in the event of a coastal storm.
- Terry Francois Boulevard would lose one lane of parking and retain its current capacity as a roadway.
- Add modest amount of new Bay fill along the Bay edge at Terry Francois Boulevard and north bank of Mission Creek at McCovey Cove.
- Tie measures into existing high ground and planned development projects at Mission Rock, Bayfront Park, Agua Vista Park, Crane Cove Park, and Pier 70.
- Incorporate NNBFs into the shoreline along the banks of Mission Creek, and bulkhead wall along Terry Francois Boulevard and South Beach with planted riprap revetments and textured vertical walls that serve a coastal flood risk management function by influencing wave runup, while also enhancing public access and wildlife habitat.
- Elevate buildings (<10) including bulkhead buildings, other buildings adjacent to the coastal flood defense structure.
- Consider demolition of some buildings (<5), such as the South Beach Harbor building and buildings bayside of the defenses at Pier 68-70, based on factors such as age, condition, ground floor elevation, and historic status.
- Build infrastructure to manage stormwater. Coordinate with SFPUC, San Francisco Public Works, and other stakeholders on changes to the combined sewer system, new pumps, green infrastructure, and other resilient building and street design opportunities and other features to reduce inland flood risk exacerbated by the coastal flood defense structures.

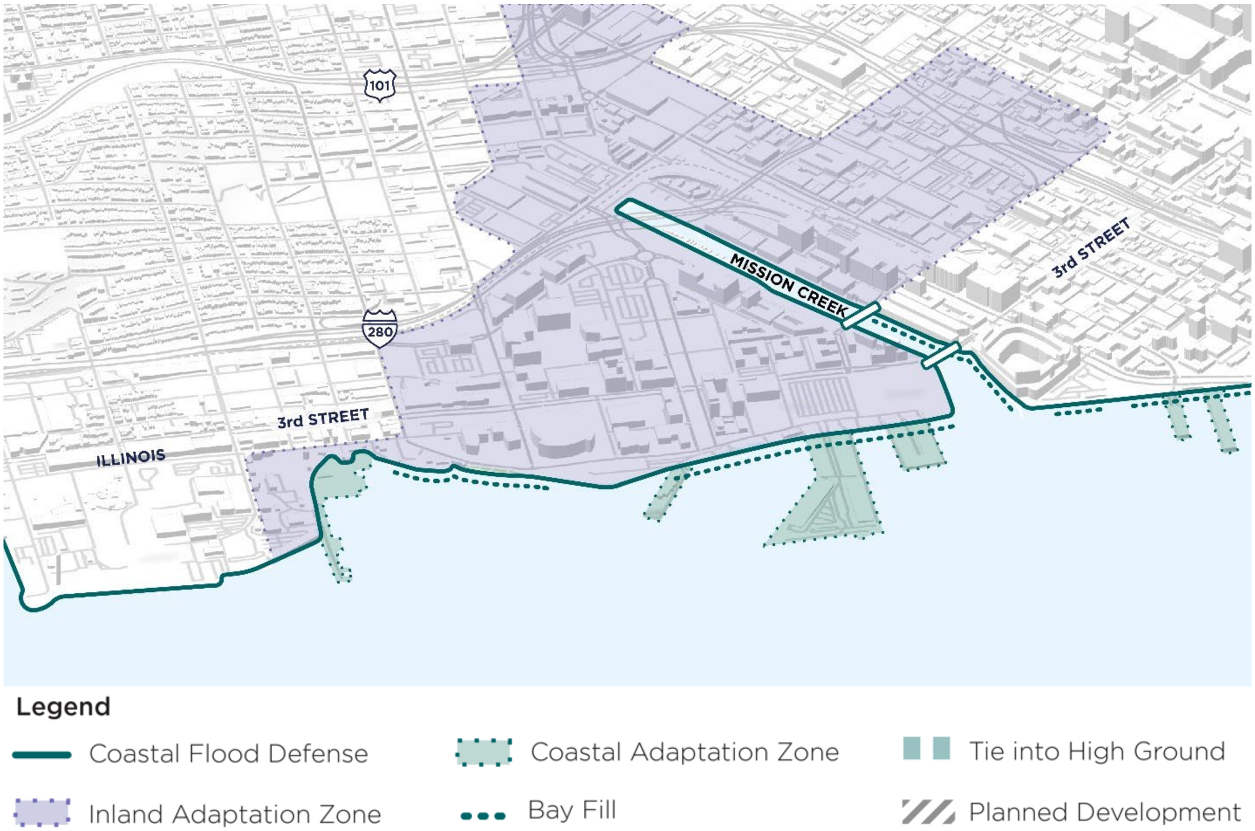


Figure A-38: Alternative E, Mission Creek/Mission Bay (Reach 3) in 2040

Alternative E would include the following actions for the 2090 adaptation (**Figure A-39**):

- Raise the shoreline by 3.5 feet by extending the landward footprint and height of levees, adding height to bulkhead walls and by reconstructing wharves at a higher elevation at the end of their assumed 50-year design life.
- Raise 3rd and 4th Street Bridges and regrade approaches, which will impact main arterial roadways and also intersecting roadways.

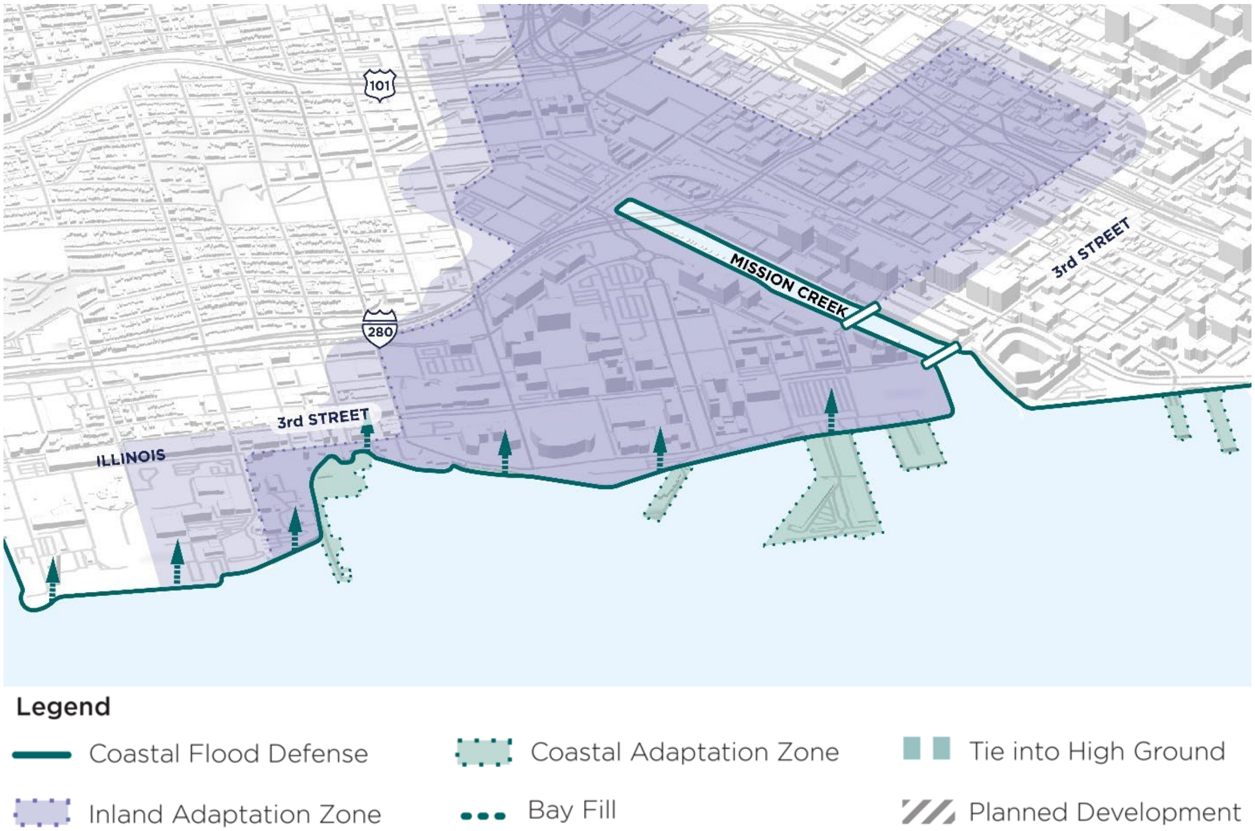


Figure A-39: Alternative E, Mission Creek/Mission Bay (Reach 3) in 2090

A-7.5.4 Islais Creek/Bayview (Reach 4)

In the Islais Creek/Bayview geography, Alternative E defends the existing shoreline to retain residential and commercial land uses in place, including POSF land uses and maritime facilities. The flood defenses consist of raising the shoreline using levees and bulkhead walls, raising and rebuilding marginal wharves, using deployable closure structures, and tying into high ground where it exists today south of Pier 70 and behind the Pier 94 Wetlands. This area of the waterfront contains large parcels independent of the combined sewer system, such that the elevated shoreline will require modification to handle stormwater in a safe and effective manner.

Alternative E would include the following actions by 2040 (**Figure A-40**):

- Elevate the Bay and creek shorelines by 4 to 6 feet using a combination of levees, raised bulkhead walls, and wharves to defend against 3.5 feet of SLR.
- Perform ground improvement to reduce lateral spreading and liquefaction risk along the coastal flood defense alignment to ensure desired seismic performance.
- Install deployable closure structures at the north and south abutments of Illinois Street Bridge over the creek to defend landward buildings and infrastructure from flood damage in the event of a coastal storm.

- Third Street Bridge is currently being re-designed to defend against several feet of SLR (FWOP condition, Section 2).
- Incorporate NNBFs into the shoreline along the banks of Islais Creek and the Pier 94 Wetlands with features that serve a coastal flood risk management function by breaking and attenuating waves, while also enhancing public access and wildlife habitat.
- No additional adaptations for existing habitat areas including Heron's Head Park beyond what is already planned under FWOP conditions (Section 2).
- Consider demolition of some buildings (<10) that overlap the coastal flood defense alignment based on factors such as age, condition, ground floor elevation, and historic status.
- Build infrastructure to manage stormwater. Coordinate with SFPUC, San Francisco Public Works, and other stakeholders on changes to the combined sewer system, new pumps, green infrastructure, other resilient building and street design opportunities, and other features to reduce inland flood risk exacerbated by the coastal flood defense structures.

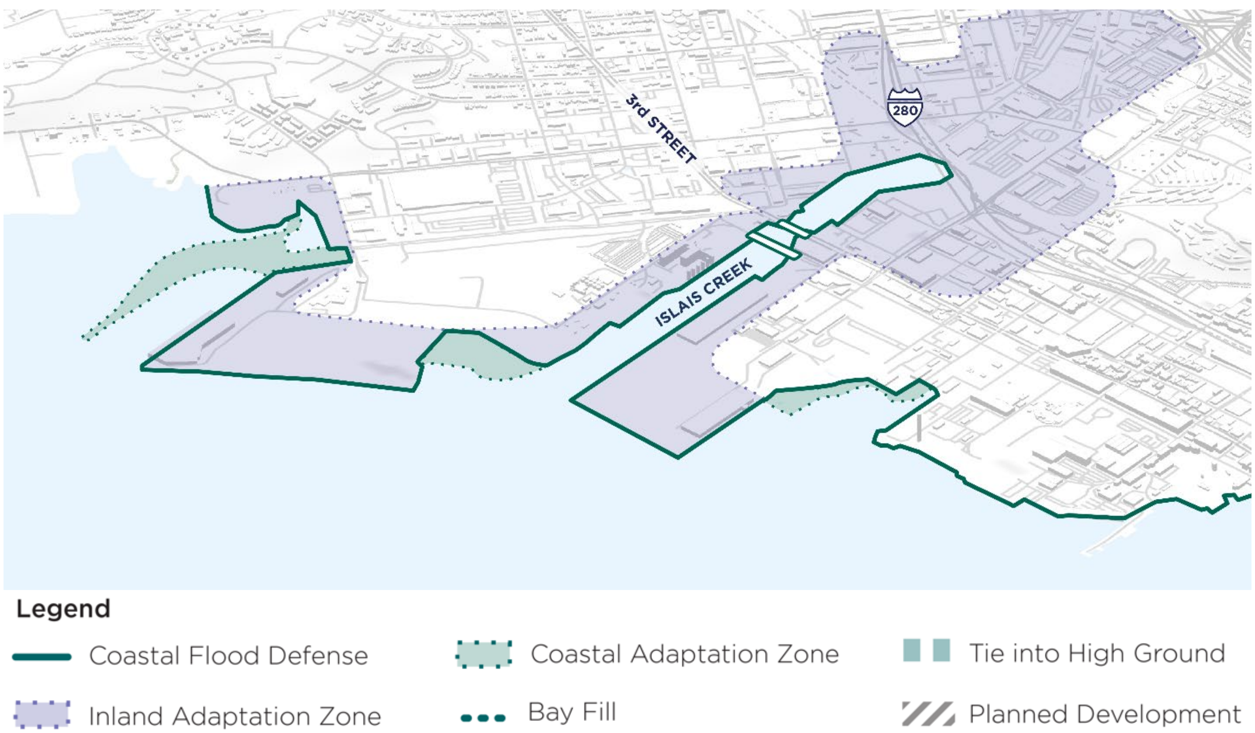


Figure A-40: Alternative E, Islais Creek/Bayview (Reach 4) in 2040

Alternative E would include the following actions for the 2090 adaptation (**Figure A-41**):

- Raise the shoreline protections by 3.5 feet by extending the landward footprint and height of levees and by reconstructing wharves at a higher elevation at the end of their assumed 50-year design life.

- Raise Illinois Street Bridge and regrade approaches, likely resulting in the loss of freight rail access to Pier 80.
- Protect existing maritime backlands and deep draft berthing, including buildings and infrastructure that support POSF and city operations and jobs.
- If needed (depending on final design of Third Street Bridge), raise Third Street Bridge to withstand up to 7 feet of SLR. *For the purposes of analysis, Alternative E assumes that Third Street Bridge is not raised again within the study period.*

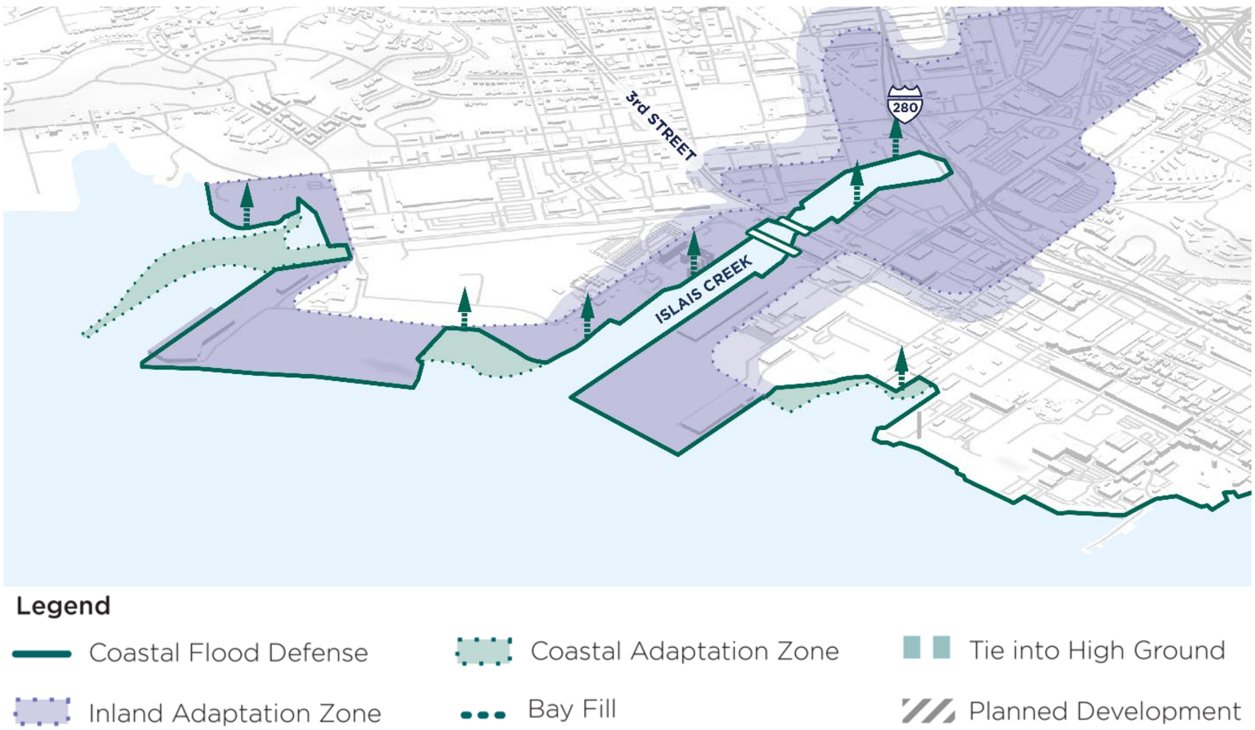


Figure A-41: Alternative E, Islais Creek/Bayview (Reach 4) in 2090

A-7.6 Alternative F: Manage the Water, Scaled for Higher Risk

Alternative F is designed to adapt the shoreline to withstand 3.5 feet of SLR, with the possibility of building higher (up to an additional 3.5 feet of SLR) closer to 2090 if SLR is projected to increase beyond the first LOD. Alternative F addresses higher rates of SLR, consistent with the USACE high RSLC curve and is consistent with State of California and City of San Francisco SLR guidance. The design crest elevation for the measures in 2040 is 15.5 feet NAVD88.

Alternative F is designed to "manage the water" by integrating typical passive flood protection measures (levees and floodwalls) along a large portion of the project length, managed retreat in select locations with new setback passive protection measures, and new water control structures near the mouths of Mission and Islais Creeks. In 2040, the water control structures would consist of tide gates near the mouths of Mission and Islais Creeks that when closed would protect against coastal floodwaters entering the protected creek channels. The protected creek channels would become engineered lagoons that would hold some stormwater to manage inland floodwaters until the gates can be opened when the Bay water level recedes. The tide gates are intended to be designed as part of an integrated inland drainage system that balances stormwater storage within the separated lagoon with active pumping to manage the runoff trapped landward of the coastal defense.

Foundations are constructed to meet the seismic performance requirements to ensure that higher water levels do not result in a high hazard to life safety during or following an earthquake, especially at the end of the study period when the coastal defenses routinely hold back Bay water.

A-7.6.1 2090 Adaptations to Alternative F

Most 2040 structures are adaptable to perform under higher water levels as sea levels continue to rise, except for portions of Reach 3 and Reach 4, where the 2090 LOD would shift inland. The 2090 adaptations include increasing the elevation of the 2040 measures and converting the tide gates to pump stations, permanently separating the engineered lagoons from the Bay. By 2090, Alternative F would require floodproofing and accommodation of some flood waters on industrial and commercial land uses east of Illinois Street. These areas would require flood monitoring and warning systems.

The features of Alternative F by reach for both the 2040 initial construction and the 2090 adaptation are described below. **Figure A-42** shows the alignment of the LOD.

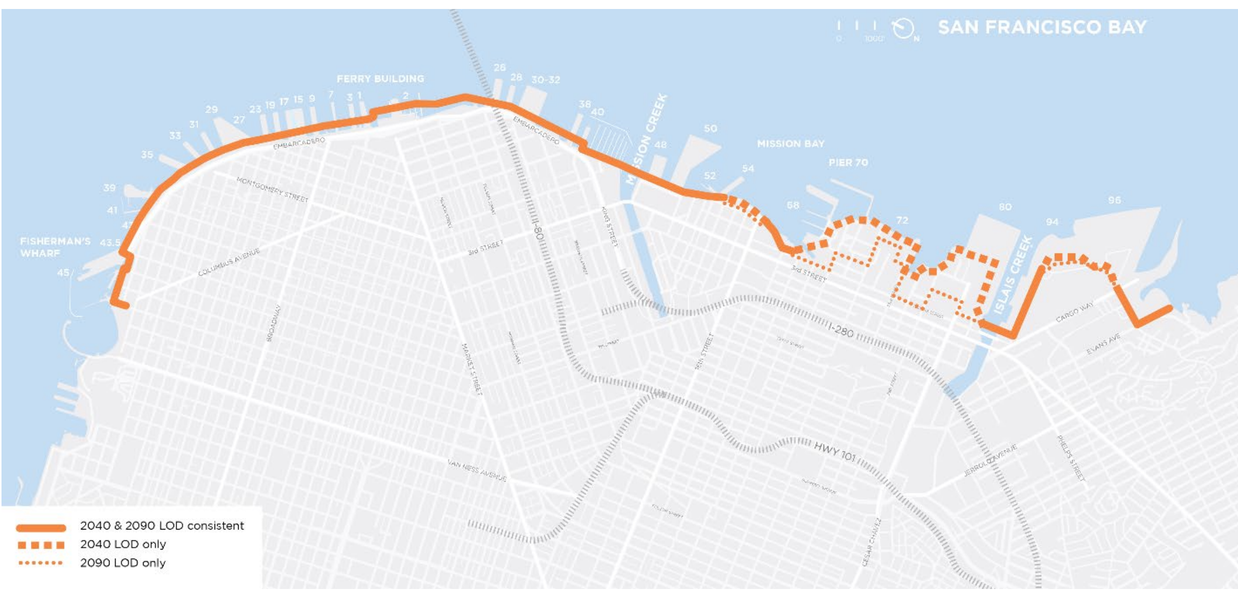


Figure A-42: Alternative F

A-7.6.2 Embarcadero (Reaches 1 and 2)

In the Embarcadero geography, Alternative F raises the shoreline with a combination of shoreline extension (beyond the existing wharf zone) and floodwalls. This alternative extends approximately 50 feet into the Bay and uses a greater amount of fill than the other alternatives as a way to reduce impacts to the Embarcadero roadway. In Reach 1, only the northbound lanes of the Embarcadero would be reconstructed, requiring less disruption during construction. However, the seismic ground improvement assumed in Reach 2 would require reconstruction of the light rail tracks and northbound lanes of the Embarcadero. When completed, Alternative F would retain the full existing corridor roadway width. The bulkhead wharves throughout this waterfront would be replaced by a new robust cantilever or tie-back wall used to retain solid fill. The bulkhead buildings would be reconstructed on top of the new fill, which would transition to the existing or new pile-supported wharves and shed buildings.

Alternative F would include the following actions by 2040 (**Figure A-43**):

- Build a coastal flood defense system that elevates the shoreline by 2.5 to 7 feet to defend against 3.5 feet of SLR. Extend the shoreline approximately 50 feet bayward along the Embarcadero roadway from Pier 35 to the Bay Bridge.
- Raise the shoreline bayward of the Ferry Building (~300 feet bayward of existing), filling the area between the new offshore cantilever wall and existing bulkhead seawall. Ferry Building would be kept in existing location.
- Defend at the shoreline through Fisherman's Wharf by constructing 1.5- to 4.5-foot-tall T-walls along Wharves J9 and J10, Taylor Street, and Pier 45 to Pier 35.
- Construct new bulkhead wall approximately 40 feet bayward of the existing seawall adjacent to the Inner Harbor along Jefferson Street between Jones and Taylor Streets. Fill the space in between the existing and new seawall and raise the shoreline elevation by several feet to minimize transportation and public realm impacts.
- Perform ground improvement to reduce lateral spreading and liquefaction risk along the coastal flood defense alignment to ensure desired seismic performance.
- Construct 2-foot-tall concrete curb around perimeter of piers from Pier 47 to Pier 24.
- Reconstruct northbound lanes of the Embarcadero roadway to meet the promenade in Reach 1. Reconstruct northbound lanes and railway in Reach 2. Southbound lanes are not impacted.
- Elevate buildings (<20) including bulkhead buildings and maintain their horizontal location relative to the existing Embarcadero Promenade and roadway, reconstructing them on top of solid fill where applicable. Provide transition from bulkhead building at new higher elevation to pier at existing lower elevation.
- Floodproof (<5) or consider demolition of (<10) buildings in Fisherman's Wharf north of Jefferson Street and west of Taylor Street, based on factors such as age, condition, ground floor elevation, and historic status.

- Build infrastructure to manage stormwater. Coordinate with SFPUC, San Francisco Public Works, and other stakeholders on changes to the combined sewer system, new pumps, green infrastructure, other resilient building and street design opportunities, and other features to reduce inland flood risk exacerbated by the coastal flood defense structures.

Figure A-43: Alternative F, Embarcadero (Reaches 1 and 2) in 2040

Alternative F would include the following actions for the 2090 adaptation (**Figure A-44**):

- Raise the shoreline by 3.5 feet to defend against 7 feet of SLR by adding a 3.5-foot-tall wall on top of measures constructed in 2040. This includes a vertical wall at the edge of the new shoreline extension between the current wharf and pier interface.
- Due to the height of the extended wall, add 3.5 feet of sloped fill behind the wall in several locations to improve public access along the shoreline edge.
- Consider demolition of additional buildings (<5) in Fisherman's Wharf along Hyde and Taylor Streets, based on factors such as age, condition, ground floor elevation, and historic status.

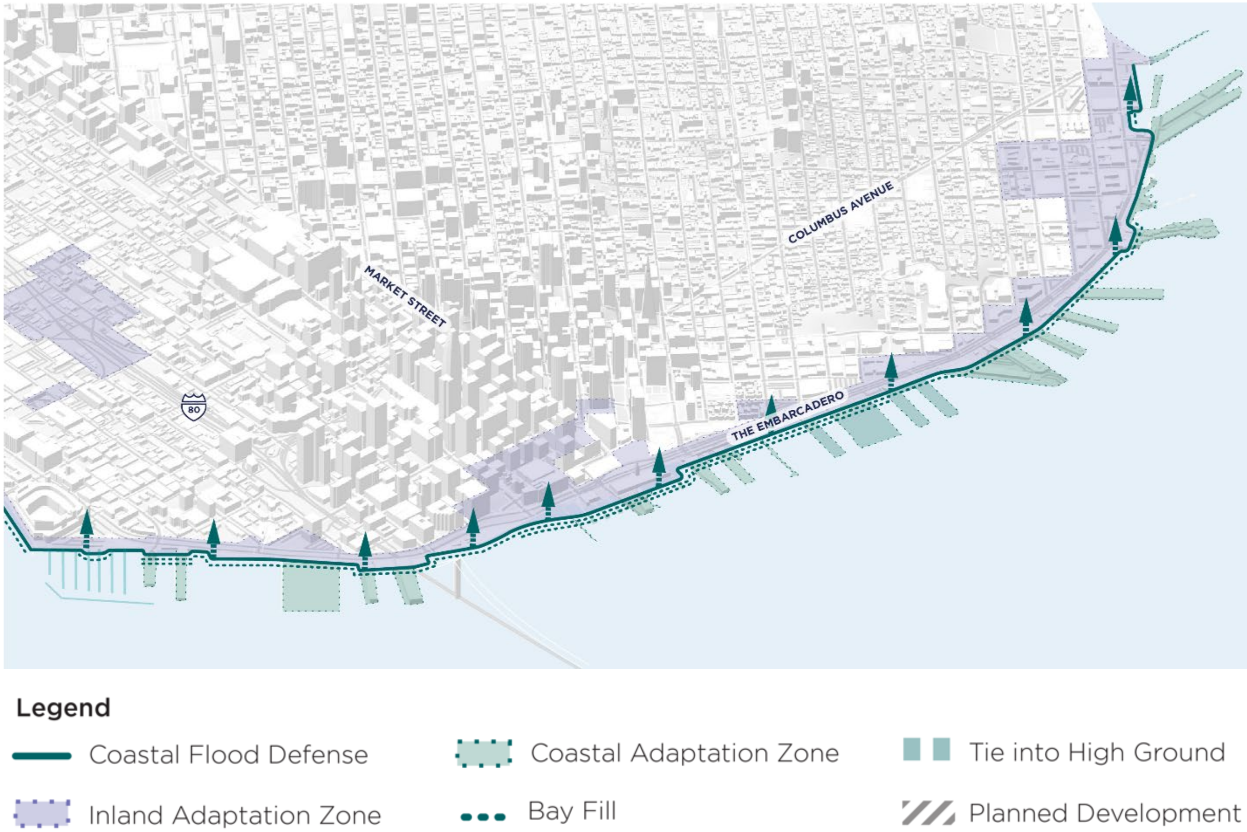


Figure A-44: Alternative F, Embarcadero (Reaches 1 and 2) in 2090

A-7.6.3 Mission Creek/Mission Bay (Reach 3)

In the Mission Creek/Mission Bay geography, Alternative F includes construction of a tide gate across McCovey Cove at the mouth of Mission Creek, which reduces the risk of flooding along all of the creek's shoreline and eliminates the need to replace and elevate the two historic bridges solely due to SLR. (The bridges may have to be rebuilt for other reasons within this timeframe, such as age, condition, and seismic vulnerability of the structures.) At the north end, the tide gate ties into a raised levee that slopes up to a new bulkhead wharf along the South Beach Harbor shoreline. To the south, the tide gate connects to a series of raised levees that tie into existing and planned high ground at Bayfront, Agua Vista and Crane Cove Parks, and the Pier 70 development. Structures bayward of the LOD would be floodproofed.

Alternative F would include the following actions by 2040 (**Figure A-45**):

- Elevate the Bay shoreline by 1.5 to 5.5 feet to defend against 3.5 feet of SLR using a combination of levees, wharves, and a shoreline extension approximately 50 feet bayward along the Embarcadero roadway from the Bay Bridge to Pier 40.
- Perform ground improvement to reduce lateral spreading and liquefaction risk along the coastal flood defense alignment to ensure desired seismic performance.

- Construct 2-foot-tall concrete curb around perimeter of piers from Pier 26 to Pier 50.
- Construct a tide gate across Mission Creek with crest elevation set to defend against up to 7 feet of SLR. Design gate in a manner that it is adaptable to permanent closure at the 2090 timeframe, thereby creating a non-tidal freshwater lagoon managed by pumps. Until 2090, it is expected that during typical Bay conditions (i.e., no high-water events), the creek will remain open and tidal. During high water or storm events, the tide gate would be closed at low tide to reduce coastal flooding and create storage for precipitation at peak runoff. The bridges and western portion of the creek shoreline do not need to be raised with the tide gate east of Third Street defending against high coastal water levels.
- Redesign for a slightly narrower Terry Francois Boulevard (approximately 93 feet) to limit the need for Bay fill to achieve the 15.5 feet crest elevation of the shoreline levee.
- Tie measures into existing high ground and planned development projects at Mission Rock, Bayfront Park, Agua Vista Park, Crane Cove Park, and Pier 70.
- Elevate bulkhead buildings (<5) and maintain their location relative to the existing Embarcadero Promenade and roadway, reconstructing them on top of solid fill where applicable. Provide transition from bulkhead building at new higher elevation to pier at existing lower elevation.
- Floodproof (<10) or consider demolition of (<5) buildings bayside of the coastal flood defense, based on factors such as age, condition, ground floor elevation, and historic status.
- Build infrastructure to manage stormwater. Coordinate with SFPUC, San Francisco Public Works, and other stakeholders on changes to the combined sewer system, new pumps, green infrastructure, other resilient building and street design opportunities, and other features to reduce inland flood risk exacerbated by the coastal flood defense structures.

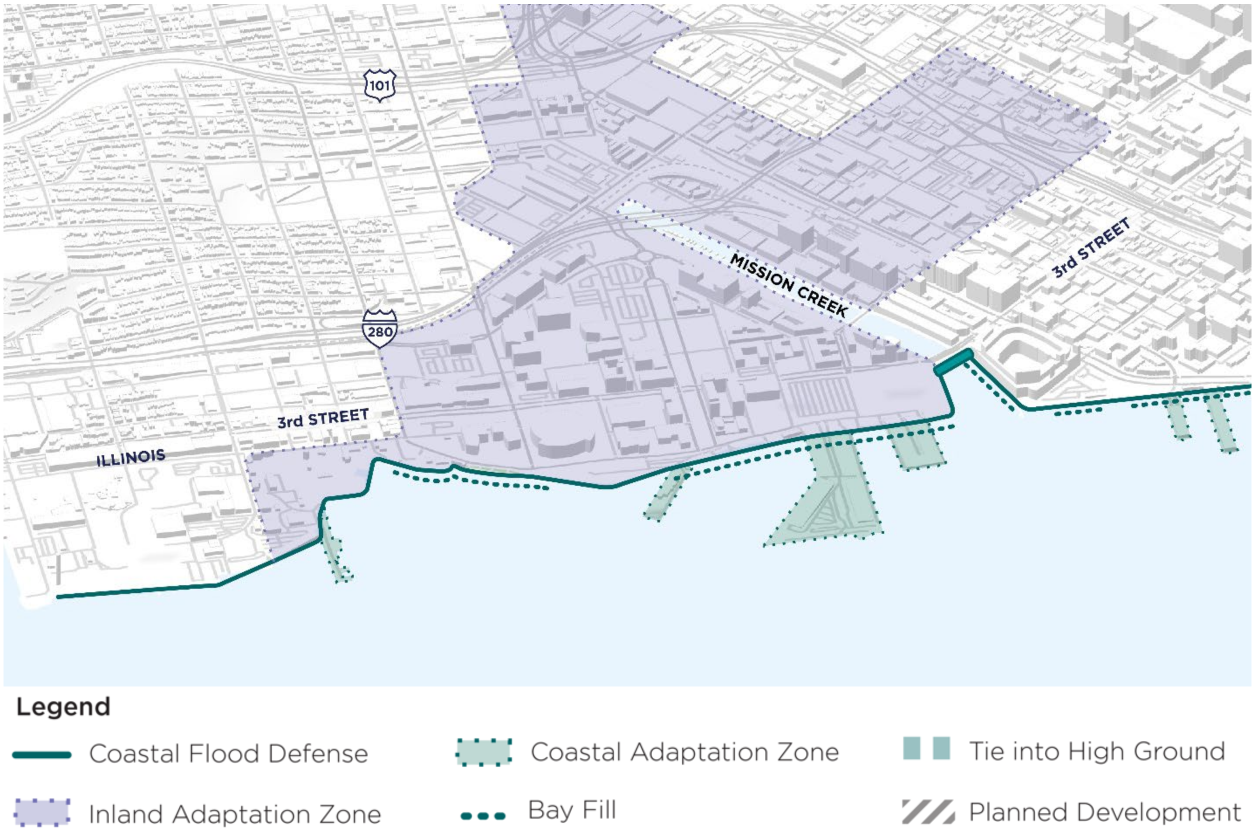


Figure A-45: Alternative F, Mission Creek/Mission Bay (Reach 3) in 2040

Alternative F would include the following actions for the 2090 adaptation (**Figure A-46**):

- Raise the coastal flood defense an additional 3.5 feet by extending the landward footprint and height of levees and adding additional height to wharves along the Bay to defend against 7 feet of SLR.
- Convert tide gate to a permanently closed hydraulic control structure to actively manage water levels in Mission Creek lagoon. The non-tidal, freshwater lagoon will require active management on a continued basis to ensure excess storage functionality and flushing for water quality purposes.
- Incorporate NNBFs into the shoreline along Crane Cove Park with features that serve a coastal flood risk management function by breaking and attenuating waves, while also enhancing public access and wildlife habitat.
- Consider demolition of (<20) buildings bayside of the coastal flood defense, based on factors such as age, condition, ground floor elevation, and historic status.
- Build additional infrastructure to manage stormwater and reduce inland flood risk exacerbated by the coastal flood defense structures.

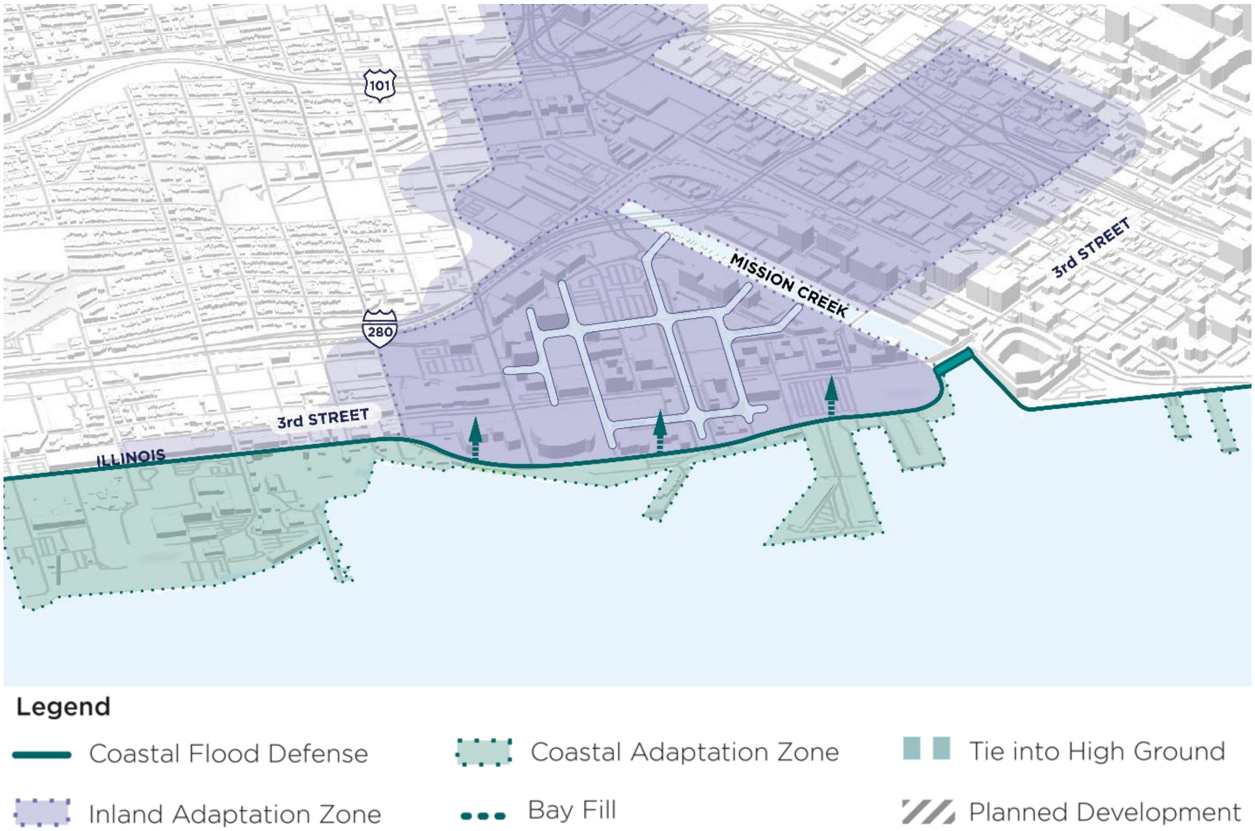


Figure A-46: Alternative F, Mission Creek/Mission Bay (Reach 3) in 2090

A-7.6.4 Islais Creek/Bayview (Reach 4)

In the Islais Creek/Bayview geography, Alternative F includes the construction of a tide gate in the creek channel east of the Third Street and Illinois Street bridges, which reduces the risk of flooding along much of the creek shoreline and eliminates the need to replace and elevate the bridges solely due to SLR. (The bridges may have to be rebuilt for other reasons within this timeframe, such as age, condition, and seismic vulnerability of the structures.) The tide gate forms a central link in the LOD for this geography, other portions of which include levees, a raised roadway (Amador Street), a short segment of floodwall, and existing high ground. Maritime and industrial working lands bayward of this primary LOD will be floodproofed in the 2040 timeframe and retreated from in the 2090 timeframe.

Alternative F would include the following features by 2040 (**Figure A-47**):

- Elevate the Bay shoreline by 2.5 to 7.5 feet with levees, walls, and raised roadways to defend against 3.5 feet of SLR.
- Perform ground improvement to reduce lateral spreading and liquefaction risk along the coastal flood defense alignment to ensure desired seismic performance.

- Construct a tide gate across Islais Creek with crest elevation set to defend against up to 7 feet of SLR. Design gate in manner that it is adaptable to permanent closure at the 2090 timeframe, creating a non-tidal freshwater lagoon managed by pumps. Until 2090, it is expected that during typical Bay conditions (i.e., no high-water events), the creek will remain open and tidal. During high water or storm events, the tide gate would be closed at low tide to reduce coastal flooding and create storage for precipitation at peak runoff. The bridges and western portion of the creek shoreline do not need to be raised with tide gate east of Illinois Street defending against high coastal water levels.
- The Third Street Bridge is currently being re-designed to defend against several feet of SLR (FWOP condition).
- Incorporate NNBFs into the shoreline along Warm Water Cove and the Pier 94 Wetlands with features that serve a coastal flood risk management function by breaking and attenuating waves, while also enhancing public access and wildlife habitat.
- No additional adaptations for existing habitat areas including Heron's Head Park beyond what is already planned under FWOP Conditions (Section 2).
- Floodproof buildings (<15) and equipment among the POSF working lands to protect maritime and industrial operations bayward of the LOD. Buildings and infrastructure would be kept in place, including POSF operations and jobs.
- Build infrastructure to manage stormwater flows impacted by the plan. Coordinate with SFPUC, San Francisco Public Works, and other stakeholders on changes to the combined sewer system, new pumps, green infrastructure, and other resilient building and street design opportunities and other features to reduce inland flood risk exacerbated by the coastal flood defense structures.

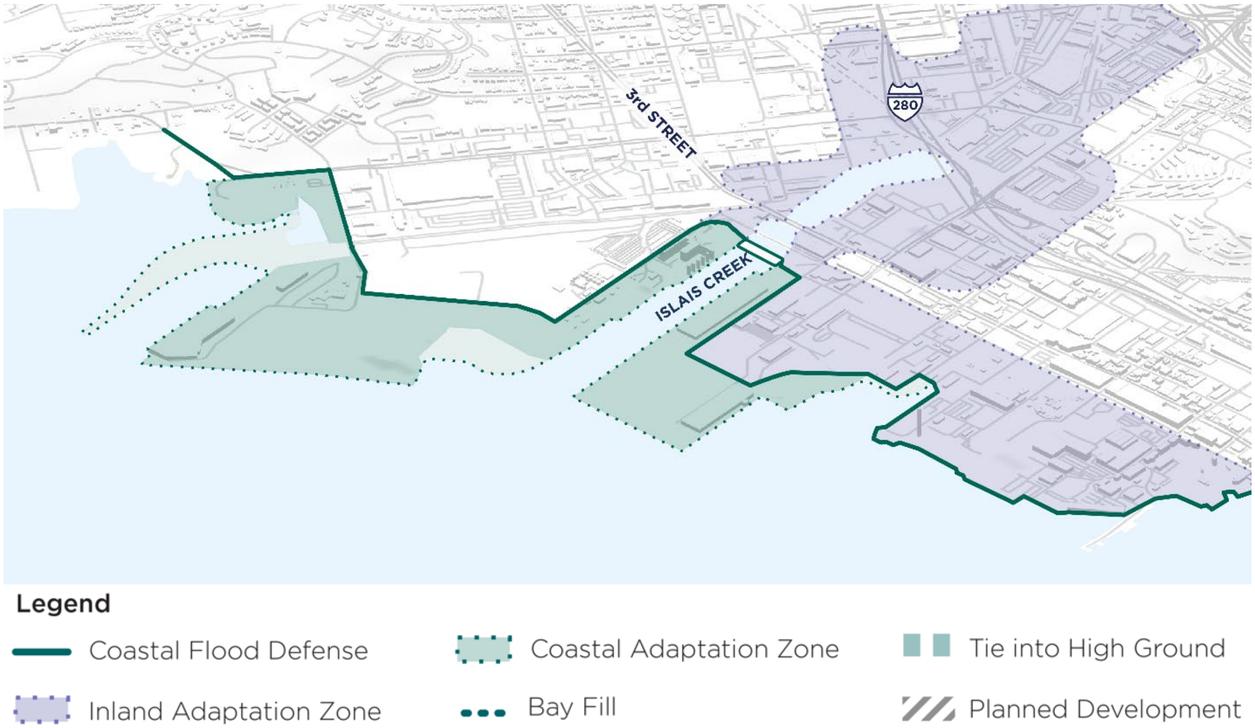


Figure A-47: Alternative F, Islais Creek/Bayview (Reach 4) in 2040

Alternative F would include the following actions for the 2090 adaptation (**Figure A-48**):

- Convert tide gate to a permanently closed hydraulic control structure to actively manage water levels in Islais Creek lagoon. The non-tidal, freshwater lagoon will require active management on a continued basis to ensure excess storage functionality and flushing for water quality purposes is fulfilled.
- Raise coastal flood risk management structures south of Islais Creek by 3.5 feet by extending the bayward footprint and height of levees and adding additional height to walls to defend against 7 feet of SLR.
- North of the creek, construct a new levee east of Illinois Street that ties into the water management structure (former tide gate) to the south and high ground to the north between 24th and 25th Streets. This would require removal of existing buildings (<15) bayward of Illinois Street.
- Retreat existing POSF maritime and industrial working lands at Pier 80, 90-92, and 94-96, including demolition of buildings (<10), de-paving of concrete and asphalt surfaces, as well as restoration and regrading to floodable space. Floodable space may provide recreation and improved habitat in vacated areas.
- Maintain, enhance, or expand NNBFs at Warm Water Cove.
- Build additional infrastructure to manage stormwater and reduce inland flood risk exacerbated by the coastal flood defense structures.

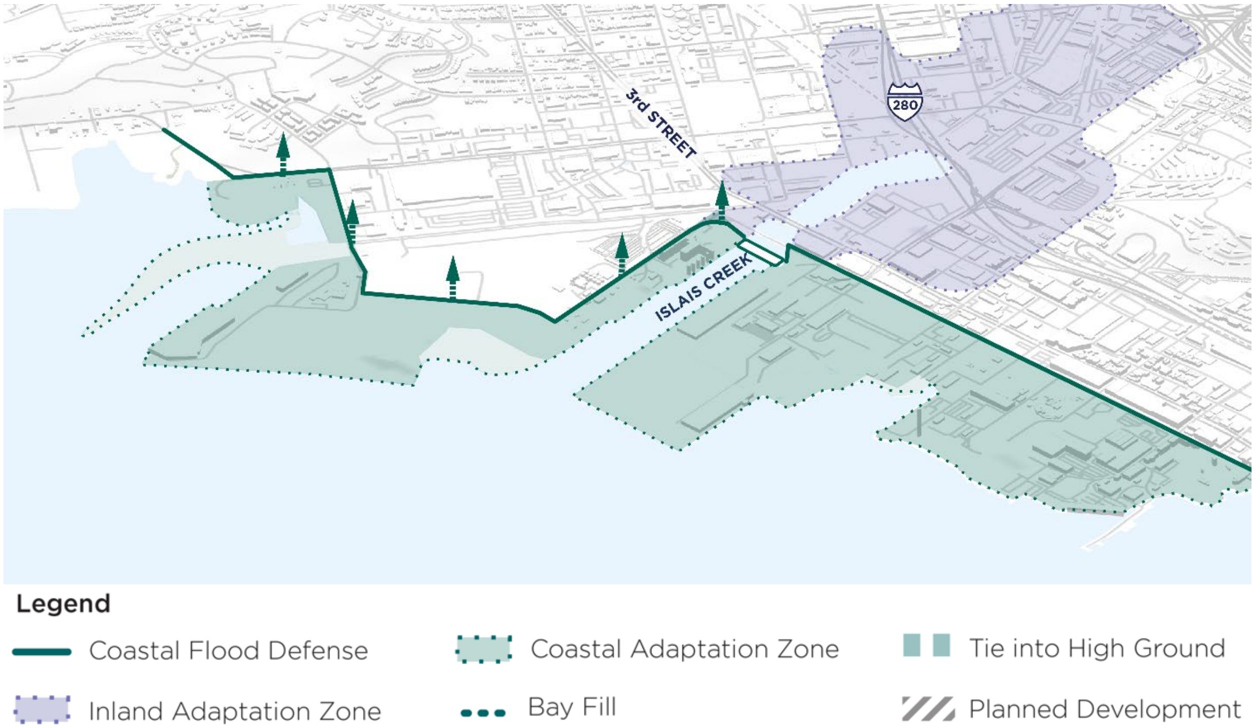


Figure A-48: Alternative F, Islais Creek/Bayview (Reach 4) in 2090

A-7.7 Alternative G: Partial Retreat, Scaled for Higher Risk

Alternative G is designed to adapt the shoreline to withstand 3.5 feet of SLR, with the possibility of building higher (up to an additional 3.5 feet of SLR) in 2090 if SLR is projected to increase beyond the first line of protection. Alternative G addresses higher rates of SLR, consistent with the USACE high RSLC curve and is consistent with State of California and City of San Francisco SLR guidance. The design crest elevation for the measures in 2040 is 15.5 feet NAVD88.

Alternative G is designed to “align with watersheds” by advancing shoreline adaptation while working with natural inland flooding patterns, floodproofing some buildings and infrastructure, and gradually retreating from the highest risk areas. In the 2040 initial construction, buildings and infrastructure throughout the waterfront, including those within the future retreat areas, will be protected using a combination of floodproofing and coastal defense structures including levees, floodwalls, seawalls, and bulkhead wharves. The bridges over Mission Creek and the Illinois Street Bridge over Islais Creek would be raised with regrading of the vehicular and rail approaches to accommodate higher water levels while maintaining transportation connections across the creek.

This alternative has the potential to significantly transform geographies in the long term by providing new floodable open spaces, relying less on inland drainage infrastructure, and restoring portions of the historic natural watersheds at the creeks. This alternative would rely heavily on policy actions in the near-term for a successful, gradual transformation.

Foundations are constructed to meet the seismic performance requirements to ensure that higher water levels do not result in a high hazard to life safety during or following an earthquake, especially at the end of the study period when the coastal defenses routinely hold back Bay water.

A-7.7.1 2090 Adaptations to Alternative G

Many of the 2040 structures are adaptable to manage risk from higher water levels as sea levels continue to rise, except for portions of Reach 3 and Reach 4, where the 2090 LOD would shift inland. The 2090 adaptative measures include increasing the elevation of 2040 structures, constructing new inland levees, and floodproofing and gradually retreating high-risk areas.

Gradual retreat along the creek banks is a defining feature of Alternative G 2090 adaptations in Reach 3 and Reach 4. Over time, this alternative would move toward a future waterfront more closely aligned with the natural watersheds to reduce both coastal and inland flood risk. In these future retreat areas, the shoreline would be converted to natural and nature-based features.

As the shoreline moves landward, the volume of inland drainage trapped behind the coastal defense decreases such that this alternative will require less stormwater management infrastructure compared to Alternatives E and F. However, there will still be a need to modify the existing wastewater system to manage inland drainage that has been transformed with the new LOD and rising Bay water levels. These modifications could include a combination of measures such as consolidation of CSD outfalls, new pumps, expanded pump capacity, green infrastructure, and other resilient building and street design opportunities.

The features of Alternative G by reach for both the 2040 initial construction and the 2090 adaptation are described below. **Figure A-49** shows the alignment of the LOD.

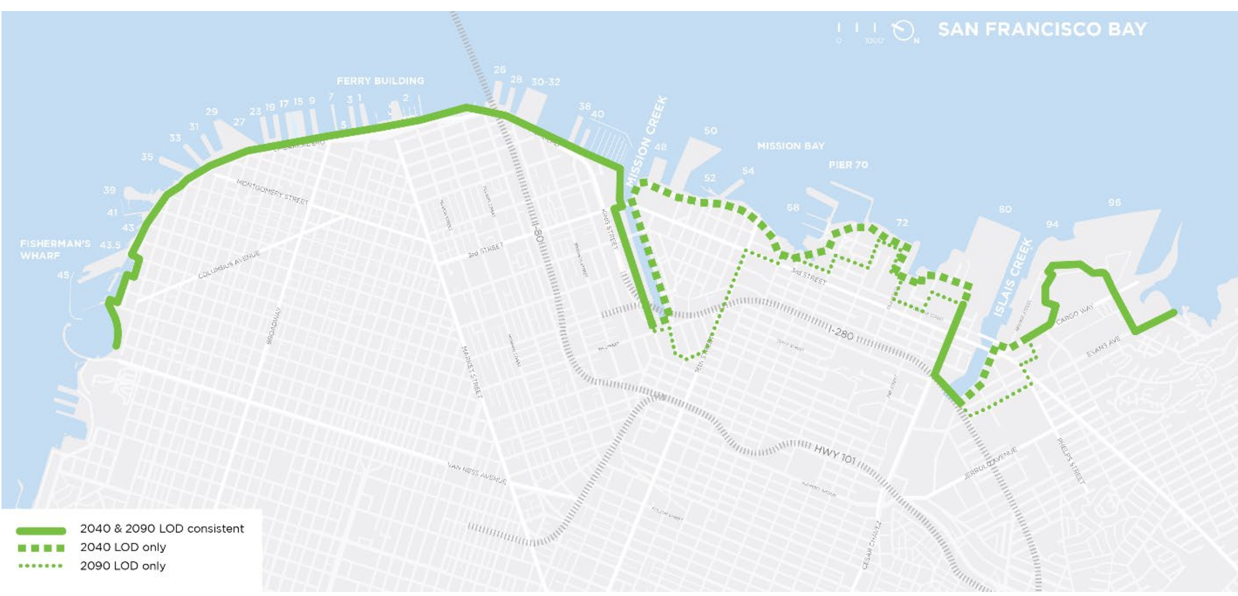


Figure A-49: Alternative G

A-7.7.2 Embarcadero (Reaches 1 and 2)

In the Embarcadero geography, Alternative G elevates the shoreline in place and reconfigures the Embarcadero roadway. It would require reconstruction and redesign of the full width of the Embarcadero roadway. Available space for the roadway would be reduced in order to gradually transition to the new elevation and retain visual and physical access to the waterfront. The wharves throughout the waterfront would be rebuilt at higher elevation. The Ferry Building and bulkhead buildings throughout this area would be raised to sit on top of the new wharves.

Alternative G would include the following features by 2040 (**Figure A-50**):

- Construct a new bulkhead seawall landward of the existing wall that enables the shoreline to be raised by 5 to 9.5 feet to defend against 5 feet of SLR between Pier 35 and the Bay Bridge. This additional elevation compared to Alternatives E and F is intended to buy additional time before a future intervention is needed, however, this assumption is expected to be re-evaluated as part of the implementation planning after TSP.
- Defend at the shoreline through Fisherman's Wharf by constructing 1.5 to 4.5-foot-tall floodwalls along Wharves J9 and J10, Jefferson Street, Taylor Street, and Pier 45 to Pier 35.
- Perform ground improvement to reduce lateral spreading and liquefaction risk along the coastal flood defense alignment to ensure desired seismic performance.
- Construct 2-foot-tall concrete curb around perimeter of piers from Pier 47 to Pier 24.
- Raising the shoreline in place requires reconstruction of the full Embarcadero roadway and results in a reduction of overall roadway width. Design of the mobility corridor and specific utilization of the available space will be done during the later Preconstruction Engineering and Design (PED) phase.
- Replace existing wharves with new ductile concrete wharves with deck elevation to match top of new bulkhead seawall.
- Elevate buildings (<20), including the Ferry Building and bulkhead buildings at existing locations. Provide transition from bulkhead building at new higher elevation to pier at existing lower elevation.
- Floodproof the Dolphin Club and consider demolition of buildings (<10) along Hyde Street, Jones Street, and Taylor Street north of Jefferson Street, based on age, condition, ground floor elevation, and historic status.
- Build infrastructure to manage stormwater. Coordinate with SFPUC, San Francisco Public Works, and other stakeholders on changes to the combined sewer system, new pumps, green infrastructure, and other resilient

building and street design opportunities and other features to reduce inland flood risk exacerbated by the coastal flood defense structures.

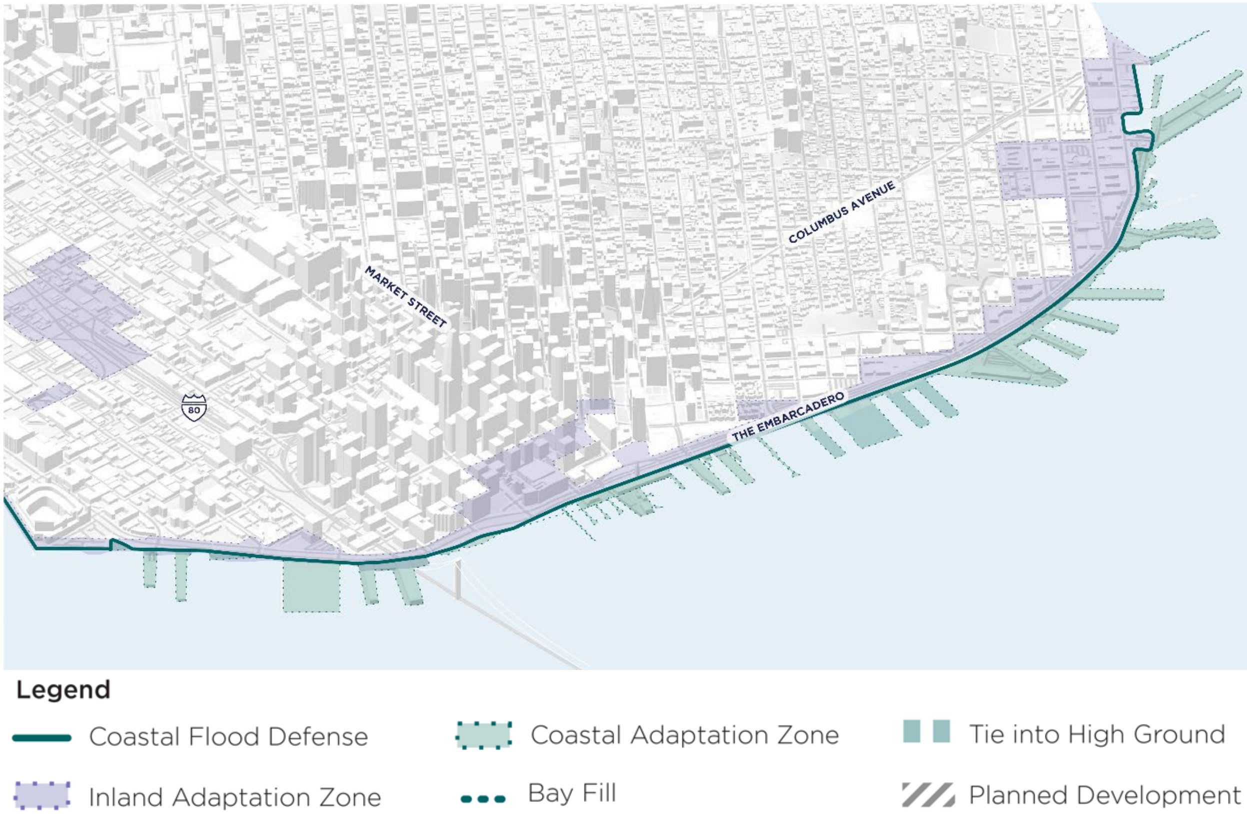


Figure A-50: Alternative G, Embarcadero (Reaches 1 and 2) in 2040

Alternative G would accomplish the following by 2090 (**Figure A-51**):

- Elevate the shoreline to defend against 7 feet of SLR by adding a 2-foot-high wall on top of the 2040 bulkhead wall between Piers 35 and 24.
- Raise height of 2040 floodwalls in Fisherman's Wharf by an additional 3.5 feet to defend against 7 feet of SLR. Consider inclusion of sloped fill behind the T-wall to decrease the exposed vertical height of the wall from the landside and provide a transition from existing city grade to the new shoreline elevation.

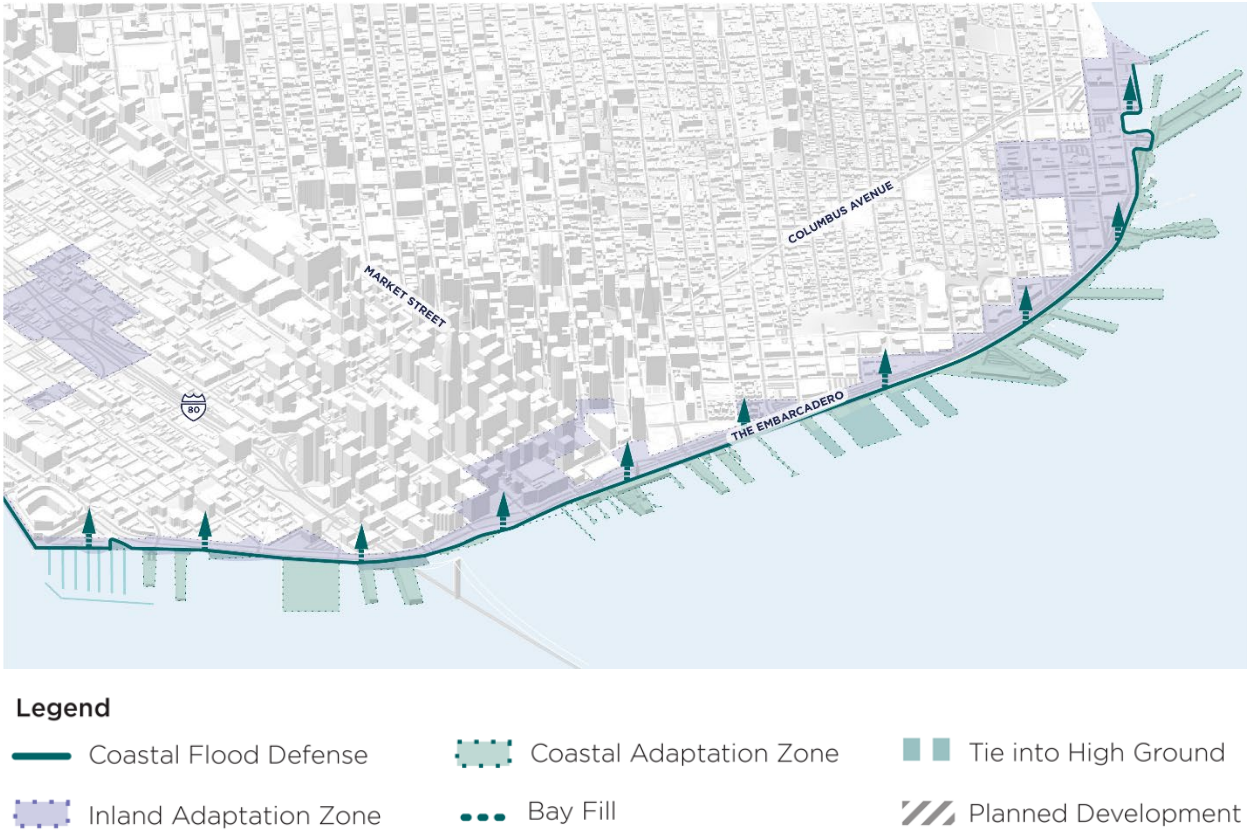


Figure A-51: Alternative G, Embarcadero (Reaches 1 and 2) in 2090

A-7.7.3 Mission Creek/Mission Bay (Reach 3)

In the Mission Creek/Mission Bay geography, Alternative G presents a transformative concept for this geography and restores a large portion of the Mission Bay neighborhood to its previous condition as a wetland and open water body. In the near term, a combination of floodwalls and levees would form a coastal defense along the shoreline of the Bay and creeks. This defense buys time for a managed retreat of the Mission Bay neighborhood that would include land use changes, acquisition of properties, demolition of some structures, and restoration of this space to natural wetland. At the landward boundary of the retreat area, a combination of floodwalls and levees tie into high ground to form a new line of coastal flood defense that limits the extent of the area for future retreat and defends landward infrastructure from coastal flooding.

This alternative was originally developed with a vision of Mission Bay transforming gradually into a designated floodable district, a bold response to the area's overlapping coastal and inland flood risks alongside seismic risk and subsidence. In this vision, walking and biking paths are elevated, buildings are floodproofed and accessible by the elevated paths. Creative solutions could be implemented to maintain or improve key transportation services, utilities, health facilities, and important cultural assets within the district. Former streets and open areas could be converted to floodable nature-based features. However, due to study limitations and challenges with the viability of this concept, the full scope of this vision is not included in the analysis. Instead, Alternative F assumes a gradual retreat of the Mission Bay neighborhood as part of the 2090 adaptations.

Alternative G would include the following actions by 2040 (**Figure A-52**):

- From the Bay Bridge to South Beach Harbor, construct a new bulkhead seawall landward of the existing wall that enables the shoreline to be raised by 3 to 6 feet to defend against 5 feet of SLR. This additional elevation compared to Alternatives E and F is intended to buy additional time before a future intervention is needed, however, this assumption is expected to be re-evaluated as part of the implementation planning after TSP.
- Raise the Mission Bay shoreline, southern creek shoreline, and along Berry Street by 2.5 to 5.5 feet using a combination of levees and walls to defend against 3.5 feet of SLR.
- Perform ground improvement to reduce lateral spreading and liquefaction risk along the coastal flood defense alignment to ensure desired seismic performance.
- Construct 2-foot-tall concrete curb around perimeter of piers from Pier 26 to Pier 50.
- Replace existing wharves with new ductile concrete wharves with deck elevation to match top of new bulkhead seawall.
- Raise Third and Fourth Street bridges over the creek by 6 feet and regrade the approaches creating a sloped embankment that requires modification to the light rail trackway and roadway corridor.
- Tie measures into existing high ground and planned development projects at Mission Rock, Bayfront Park, Agua Vista Park, Crane Cove Park, and Pier 70.
- Incorporate NNBFs into the shoreline along the banks of Mission Creek that serve a coastal flood risk management function by influencing wave runup, while also enhancing public access and wildlife habitat.
- Elevate bulkhead buildings (<5) at existing locations. Provide transition from bulkhead building at new higher elevation to pier at existing lower elevation.
- Floodproof buildings (<15) bayside of the LOD on the north side of Mission Creek.
- Build infrastructure to manage stormwater. Coordinate with SFPUC, San Francisco Public Works, and other stakeholders on changes to the combined sewer system, new pumps, green infrastructure, and other resilient building and street design opportunities and other features to reduce inland flood risk exacerbated by the coastal flood defense structures.

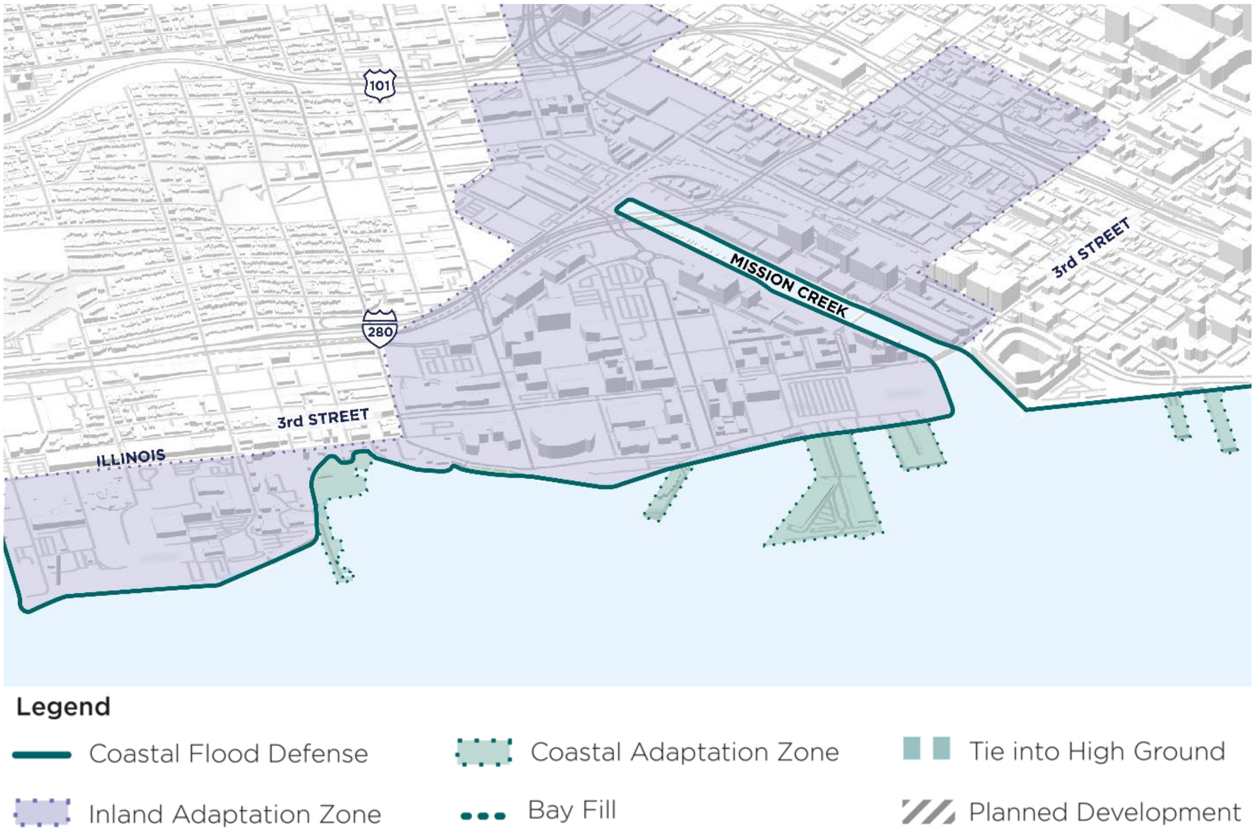


Figure A-52: Alternative G, Mission Creek/Mission Bay (Reach 3) in 2040

Alternative G would include the following actions for the 2090 adaptation (**Figure A-53**):

- From the Bay Bridge to South Beach Harbor, elevate the shoreline to defend against 7 feet of SLR by adding a 2-foot-high wall on top of the 2040 bulkhead wall.
- Construct a new levee that raises the ground elevation by 4 feet to 9 feet along a landward alignment that generally follows King, Berry, 8th, and 16th Streets. The levee is designed to defend against up to 7 feet of SLR. Deployable closure structures would be installed in the levee where the LOD crosses the Caltrain right-of-way.
- Retreat from buildings (>25) and infrastructure bayside of the LOD, including demolition and de-paving. This includes severing the light rail connection between the Southern Waterfront, Muni Metro East rail yard, and the downtown corridor. Additionally, the north-south vehicular arterial of 3rd Street would be eliminated between 16th and King Streets.
- Build additional infrastructure to manage stormwater and reduce inland flood risk exacerbated by the coastal flood defense structures.

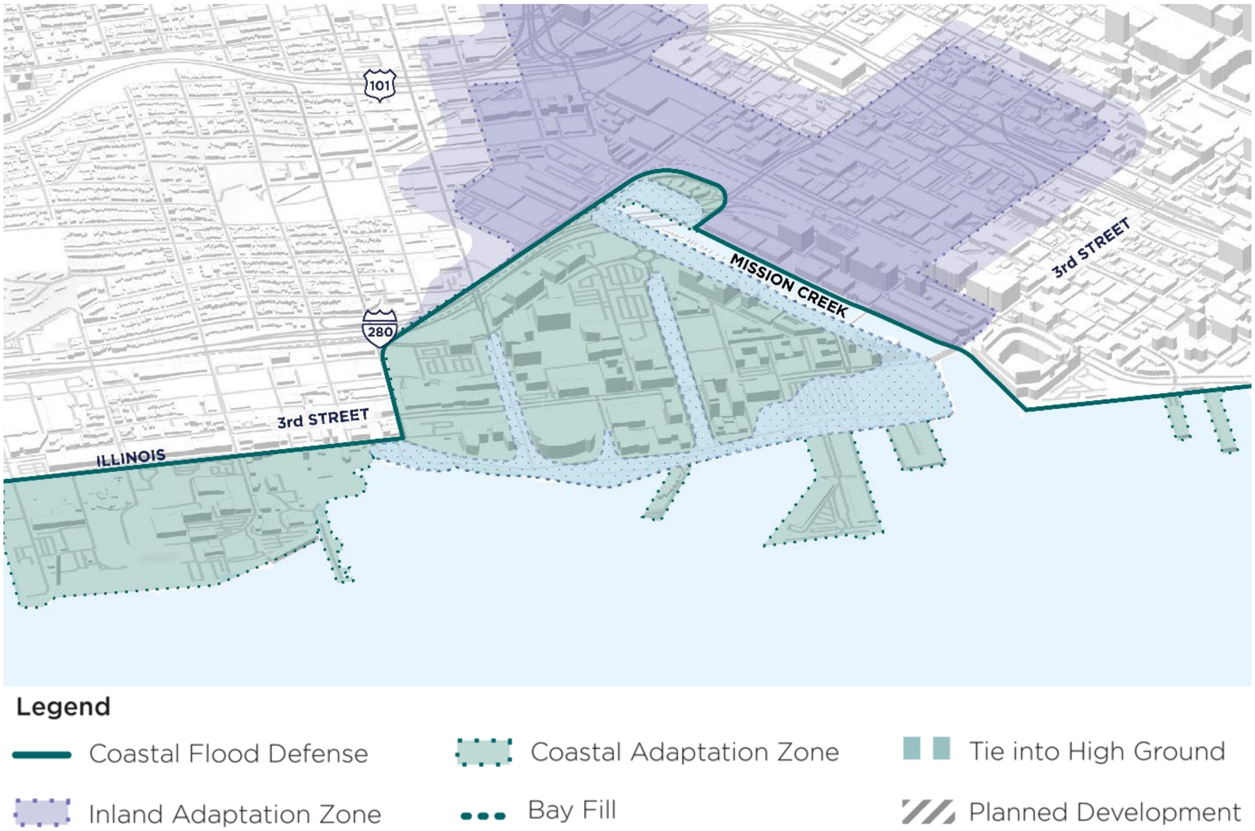


Figure A-53: Alternative G, Mission Creek/Mission Bay (Reach 3) in 2090

A-7.7.4 Islais Creek/Bayview (Reach 4)

In Islais Creek/Bayview, Alternative G presents a transformative concept and lays groundwork for the potential to eventually restore some of this area to its previous condition as a coastal wetland. Alternative G constructs a series of levees linked to existing high ground. Maritime and industrial working lands bayside of this coastal flood defense will initially be floodproofed to reduce risk but will eventually become part of a managed retreat.

This alternative incorporates several natural and nature-based features to reduce risk, improve the environment, and provide recreational and social benefits. In the long term, it requires a significant reconfiguration of the transportation network and other city-serving infrastructure. It also requires removal and potential relocation of commercial and industrial land uses. *For purposes of this study, these land uses are assumed to be removed. Potential relocation costs and benefits are not included in this alternative.*

Alternative G would include the following actions by 2040 (**Figure A-54**):

- Construct levees that raise the ground by 1.5 to 5.5 feet and tie into high ground to defend against 3.5 feet of SLR. Utilize the existing Caltrain embankment as part of the LOD near the head of the creek.

- Perform ground improvement to reduce lateral spreading and liquefaction risk along the coastal flood defense alignment to ensure desired seismic performance.
- Raise Illinois Street Bridge and regrade approaches, creating embankment causeways from Cesar Chavez to Cargo Way. This is expected to result in the loss of freight rail access to Pier 80 and potentially the Intermodal Cargo Transfer Freight (ICTF) Rail Yard.
- The Third Street Bridge is currently being re-designed to defend against several feet of SLR (FWOP condition).
- Incorporate NNBFs into the shoreline along the banks of Islais Creek, Warm Water Cove, and the Pier 94 Wetlands that serve a coastal flood risk management function by influencing wave runup, while also enhancing public access and wildlife habitat.
- No additional adaptations for existing habitat areas including Heron’s Head Park beyond what is already planned under FWOP Conditions (Section 2).
- Floodproof buildings (>25), equipment, and infrastructure within the POSF maritime and industrial working lands to protect operations at Piers 80, 90-92, and 94-96 from physical flood damages.
- Consider demolition of buildings (<5) that overlap the LOD along the creek edge based on age, condition, ground floor elevation, and historic status.
- Develop comprehensive land use tools and policies to gradually vacate portions of the adaptation zones. This could include voluntary buyouts, rezoning and land use policy changes, grants, loans and incentives, and other assistance programs. The cost of these nonstructural actions are not included as part of this alternative.
- Build infrastructure to manage stormwater. Coordinate with SFPUC, San Francisco Public Works, and other stakeholders on changes to the combined sewer system, new pumps, green infrastructure, other resilient building and street design opportunities, and other features to reduce inland flood risk exacerbated by the coastal flood defense structures.

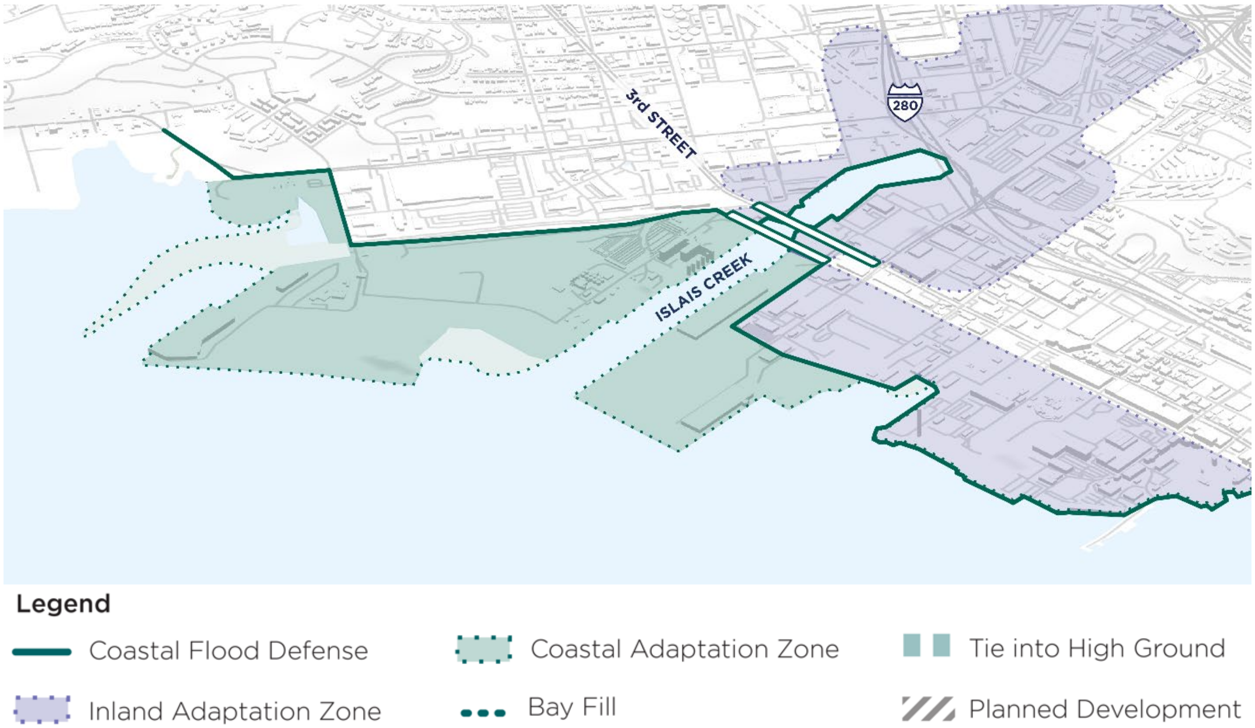


Figure A-54: Alternative G, Islais Creek/Bayview (Reach 4) in 2040

Alternative G would include the following actions for the 2090 adaptation (**Figure A-55**):

- Along south banks of Islais Creek, construct new levee along Evans Avenue, which results in a retreat between the Caltrain line and Third Street. The new levee raises the shoreline by up to 8 feet to defend against up to 7 feet of SLR.
- Along Islais Creek north bank, raise the 2040 levee along Cesar Chavez by 3.5 feet and tie into existing high ground at the Caltrain Embankment.
- Along Illinois Street, construct new levee that elevates the ground up to 4 feet between Cesar Chavez and 24th Street.
- Gradually vacate limited areas near Islais Creek Channel over several decades (no residential areas vacated).
- Retreat existing POSF maritime and industrial working lands at Piers 80, 90-92, and 94-96, including de-paving concrete and asphalt surfaces, and restoring and regrading to floodable space. Floodable space may provide recreation and improved habitat in vacated areas.
- Further incorporate NNBFs bayside of the LOD with features that serve a coastal flood risk management function while also enhancing public access and wildlife habitat.
- Acquire and consider demolition of buildings (>25) bayside of the LOD based on age, condition, ground floor elevation, and historic status.

- Build additional infrastructure to manage stormwater and reduce inland flood risk exacerbated by the coastal flood defense structures.

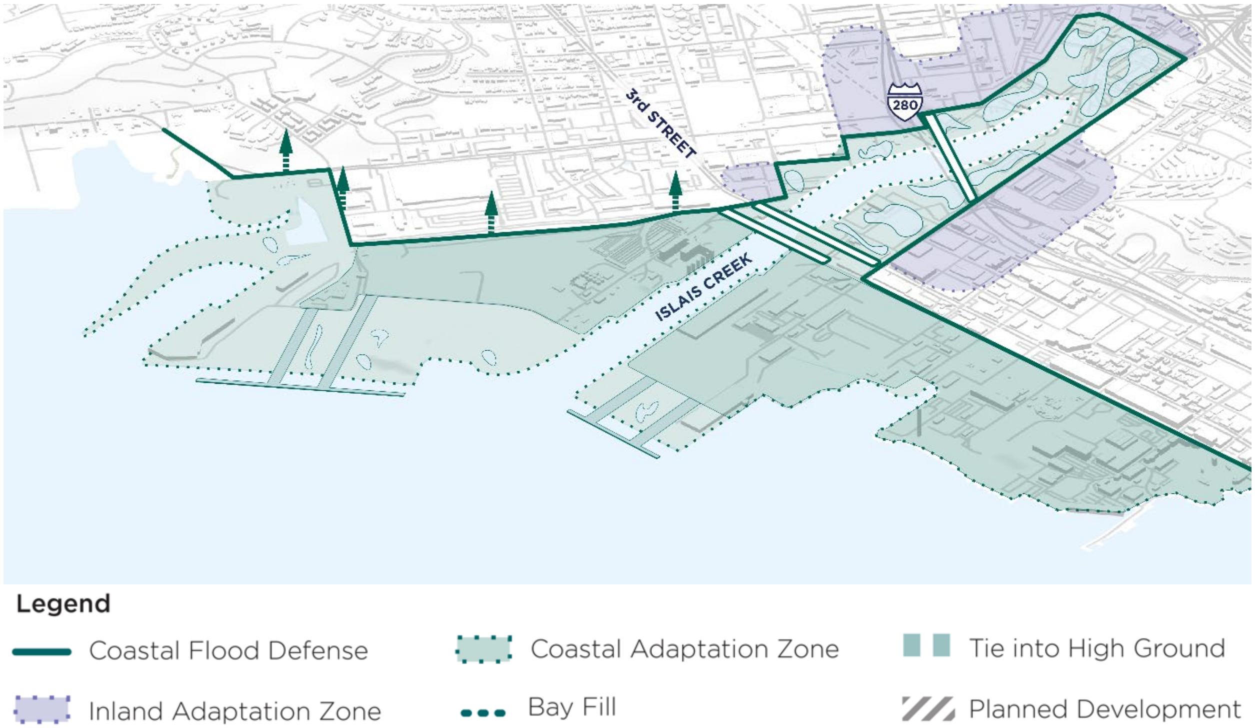


Figure A-55: Alternative G, Islais Creek/Bayview (Reach 4) in 2090

Section A-8. Evaluation of Focused Array

An NED evaluation of the focused array was conducted by the PDT. NED benefits were estimated with G2CRM and several important metrics outside of G2CRM, notably OMRR&R costs and the relative costs of future changes to the SFMTA transit system and the SFPUC combined sewer system under the FWOP and FWP scenarios.

A detailed description of the implementation of G2CRM including the analytical process, relevant inputs, asset inventory creation, modeling actuation, results for each subsection of the study area and results analysis is provided in *Appendix E: Economic and Social Considerations*.

A-8.1 Costs

The costs for the plans without seismic improvements are shown in **Table A-20** through **Table A-27** by reach at FY24 prices levels. Seismic improvement costs are not considered when calculating net benefits for this study, in accordance with the requirements of Section 152 of WRDA 2020, as amended. The first four tables show the cost of the 2040 action, while the second four tables show the cost of the full reach-level plan (meaning 2040 actions and 2065, 2090, and 2115 actions where applicable). Under the High SLC curve, the assumption is that the higher cost would represent the total, while under the Intermediate and Low SLC curves, the cost would only include the

2040 action. (An exception to this is Alternative D, where the 2090 action is needed under the Intermediate RSLC curve.) Note that these costs do not include seismic costs.

The Real Estate costs were provided by the PDT's Real Estate team; the derivation of those costs is discussed in *Appendix F: Real Estate Plan*. The estimates on construction duration were provided by the Engineering Team; a discussion of those estimates can be found in the *Appendix C: Cost Engineering*. The OMRR&R rates were also estimated by the Engineering team. The nonstructural alternatives are assumed to have no OMRR&R, while the structural alternatives used an OMRR&R rate of 0.5% of the capital cost per year. An exception to this is Alternative F in Reaches 3 and 4, where the water management structures were assumed to have a higher OMRR&R rate of 2% per year.

Though the seismic costs are not used in benefit calculation due to the WRDA language, they are still real costs that are incurred. Additionally, the amount of cost that is attributed to "seismic" is not equal across measures; some measures have a larger percentage of their total cost considered seismic while others have a lower percentage. For example, 86% of the cost of Alternative D is considered seismic while only 36% of the cost of Alternative G is considered seismic (though the seismic costs are relatively close in cost between the structural plans). In plan selection, then, the marginal costs including seismic between plans should be considered. For reference, the first costs with seismic improvements are provided in **Table A-28** and **Table A-29**.

Table A-20: Costs Without Seismic, Reach 1, 2040

($1,000s)

Plan	Total Construction	Real Estate	Duration	IDC	Subtotal AAC	OMRR&R	Total AAC
B Intermediate	16,196	3	33	478	-	478	16,196
B High	79,320	3	164	2,341	-	2,341	79,320
C	127,108	72	9,758	4,031	636	4,667	127,108
D	92,602	96	9,674	3,012	463	3,475	92,602
E	3,246,873	180	678,917	115,631	16,234	131,865	3,246,873
F	1,964,731	180	410,823	69,970	9,824	79,794	1,964,731
G	1,071,822	180	224,117	38,171	5,359	43,530	1,071,822

Table A-21: Costs Without Seismic, Reach 2, 2040

($1,000s)

Plan	Total Construction	Real Estate	Duration	IDC	Subtotal AAC	OMRR&R	Total AAC
B Intermediate	20,685	3	43	611	-	611	20,685
B High	109,778	3	226	3,240	-	3,240	109,778
C	203,803	72	15,646	6,464	1,019	7,483	203,803
D	119,155	96	12,448	3,876	596	4,472	119,155
E	4,097,548	180	856,792	145,926	20,488	166,414	4,097,548
F	7,477,883	180	1,563,615	266,310	37,389	303,699	7,477,883
G	2,898,048	180	605,978	103,208	14,490	117,698	2,898,048

Table A-22: Costs Without Seismic, Reach 3, 2040
($1,000s)

Plan	Total Construction	Real Estate	Duration	IDC	Subtotal AAC	OMRR&R	Total AAC
B Intermediate	319,421	3	658	9,428	-	9,428	319,421
B High	632,903	3	1,305	18,680	-	18,680	632,903
C	385,243	72	29,574	12,218	1,926	14,144	385,243
D	345,323	96	36,076	11,234	1,727	12,960	345,323
E	4,350,434	180	909,670	154,932	21,752	176,684	4,350,434
F	2,539,303	180	530,965	90,432	50,786	141,218	2,539,303
G	1,911,662	180	399,726	68,080	9,558	77,638	1,911,662

Table A-23: Costs Without Seismic, Reach 4, 2040
($1,000s)

Plan	Total Construction	Real Estate	Duration	IDC	Subtotal AAC	OMRR&R	Total AAC
B Intermediate	47,679	3	98	1,407	-	1,407	47,679
B High	120,125	3	248	3,545	-	3,545	120,125
C	745,630	72	57,240	23,648	3,728	27,376	745,630
D	814,898	96	85,134	26,510	4,074	30,584	814,898
E	4,038,817	180	844,511	143,834	20,194	164,028	4,038,817
F	746,511	180	156,094	26,586	14,930	41,516	746,511
G	1,584,375	180	331,291	56,424	7,922	64,346	1,584,375

Table A-24: Costs Without Seismic, Reach 1, All Actions

($1,000s)

Plan	Total Construction	Real Estate	Duration	IDC	Subtotal AAC	OMRR&R	Total AAC
B Intermediate	32,985	3	68	974	-	974	32,985
B High	199,350	3	411	5,884	-	5,884	199,350
C	127,108	72	9,758	4,031	636	4,667	127,108
D	191,173	96	19,972	6,219	956	7,175	191,173
E	3,369,530	180	704,564	119,999	16,848	136,847	3,369,530
F	1,971,113	180	412,157	70,197	9,856	80,053	1,971,113
G	1,104,739	180	230,999	39,343	5,524	44,867	1,104,739

Table A-25: Costs, Reach 2 Without Seismic, All Actions

($1,000s)

Plan	Total Construction	Real Estate	Duration	IDC	Subtotal AAC	OMRR&R	Total AAC
B Intermediate	78,264	3	161	2,310	-	2,310	78,264
B High	601,180	3	1,239	17,744	-	17,744	601,180
C	203,803	72	15,646	6,464	1,019	7,483	203,803
D	448,469	96	46,852	14,589	2,242	16,832	448,469
E	4,341,251	180	907,750	154,605	21,706	176,311	4,341,251
F	7,483,373	180	1,564,763	266,505	37,417	303,922	7,483,373
G	2,913,151	180	609,136	103,746	14,566	118,312	2,913,151

Table A-26: Costs, Reach 3 Without Seismic, All Actions

($1,000s)

Plan	Total Construction	Real Estate	Duration	IDC	Subtotal AAC	OMRR&R	Total AAC
B Intermediate	409,445	3	844	12,085	-	12,085	409,445
B High	1,443,015	3	2,974	42,590	-	42,590	1,443,015
C	385,243	72	29,574	12,218	1,926	14,144	385,243
D	598,300	96	62,505	19,463	2,991	22,455	598,300
E	4,601,727	180	962,215	163,881	23,009	186,890	4,601,727
F	2,883,613	180	602,960	102,694	57,672	160,366	2,883,613
G	2,213,234	180	462,784	78,820	11,066	89,886	2,213,234

Table A-27: Costs, Reach 4 Without Seismic, All Actions

($1,000s)

Plan	Total Construction	Real Estate	Duration	IDC	Subtotal AAC	OMRR&R	Total AAC
B Intermediate	73,384	3	151	2,166	-	2,166	73,384
B High	306,609	3	632	9,050	-	9,050	306,609
C	745,630	72	57,240	23,648	3,728	27,376	745,630
D	1,015,130	96	106,052	33,023	5,076	38,099	1,015,130
E	4,197,848	180	877,765	149,498	20,989	170,487	4,197,848
F	1,141,645	180	238,717	40,657	22,833	63,490	1,141,645
G	1,839,560	180	384,650	65,512	9,198	74,710	1,839,560

Table A-28: Reach-Level Construction Costs Including Seismic (2040)

	1	2	3	4
B Intermediate	16,196	20,685	319,421	47,679
B High	79,320	109,778	632,903	120,125
C	684,152	3,241,445	1,591,405	6,098,915
D	624,781	2,604,581	1,748,036	6,548,713
E	4,484,113	9,588,049	5,853,343	5,962,299
F	2,509,042	10,212,220	3,556,641	1,538,850
G	1,364,499	4,248,196	2,561,430	4,031,910

Table A-29: Reach-Level Construction Costs Including Seismic, All Actions

	1	2	3	4
B Intermediate	32,985	78,264	409,445	73,384
B High	199,350	601,180	1,443,015	306,609
C	684,152	3,241,445	1,591,405	6,098,915
D	723,352	2,933,894	2,001,013	6,748,945
E	4,606,770	9,831,753	6,104,636	6,121,330
F	2,515,459	10,217,741	3,924,345	1,944,970
G	1,421,188	4,381,083	2,922,690	4,337,770

A-8.2 NED Evaluation

Table A-30,**Table A-31**,and **Table A-32** present the NED evaluation for the alternatives by reach for the Low, Intermediate, and High RSLC curves, respectively.

Table A-30: NED Evaluation, Low RSLC ($1000s, PV)

Reach	Damages	Benefits, 2040-2089	Benefits, 2090 -2140	Total Benefits	Cost	Net Benefits
FWOP						
1	375,852					
2	729,221					
3	898,963					
4	1,606,779					
Total	3,610,815					
Alternative B						
1	371,323	2,528	2,000	4,528	16,229	(11,701)
2	512,039	125,851	91,331	217,182	20,728	196,454
3	291,914	411,219	195,830	607,049	320,079	286,970
4	1,435,775	141,510	29,495	171,005	47,778	123,227
Total	2,611,051	681,108	318,656	999,764	404,814	594,950
Alternative C						
1	371,323	2,528	2,000	4,528	158,443	(153,915)
2	512,040	125,850	91,332	217,182	254,046	(36,864)
3	307,239	403,161	188,563	591,724	480,214	111,510
4	1,443,508	136,071	27,200	163,271	929,445	(766,174)
Total	2,634,110	667,610	309,095	976,705	1,822,148	(845,443)
Alternative D						
1	371,323	2,528	2,000	4,528	117,996	(113,468)
2	512,039	125,851	91,331	217,182	151,831	65,351
3	309,223	402,711	187,028	589,739	440,020	149,719
4	1,441,398	137,248	28,133	165,381	1,038,365	(872,984)
Total	2,633,983	668,338	308,492	976,830	1,748,212	(771,382)

Reach	Damages	Benefits, 2040-2089	Benefits, 2090 -2140	Total Benefits	Cost	Net Benefits
Alternative E						
1	2,128	331,581	42,143	373,724	4,476,963	(4,103,239)
2	4,983	556,930	167,308	724,238	5,649,920	(4,925,682)
3	17,328	648,488	233,146	881,634	5,998,613	(5,116,979)
4	14,440	1,483,971	108,368	1,592,339	5,568,938	(3,976,599)
Total	38,879	3,020,970	550,965	3,571,935	21,694,434	(18,122,499)
Alternative F						
1	2,128	331,581	42,143	373,724	2,709,077	(2,335,353)
2	4,983	556,930	167,308	724,238	10,310,908	(9,586,670)
3	115,034	558,014	225,914	783,928	4,794,508	(4,010,580)
4	1,497,785	85,208	23,786	108,994	1,409,502	(1,300,508)
Total	1,619,930	1,531,733	459,151	1,990,884	19,223,995	(17,233,111)
Alternative G						
1	2,128	331,581	42,143	373,724	1,477,886	(1,104,162)
2	4,983	556,930	167,308	724,238	3,995,985	(3,271,747)
3	175,905	527,394	195,663	723,057	2,635,903	(1,912,846)
4	1,548,466	47,118	11,196	58,314	2,184,621	(2,126,307)
Total	1,731,482	1,463,023	416,310	1,879,333	10,294,395	(8,415,062)

Table A-31: NED Evaluation, Intermediate RSLC ($1,000s, PV)

Reach	Damages	Benefits, 2040-2089	Benefits, 2090 -2140	Total Benefits	Cost	Net Benefits
FWOP						
1	430,228					
2	1,576,334					
3	2,113,359					
4	1,834,863					
Total	5,954,784					
Alternative B						
1	379,122	8,313	42,793	51,106	33,053	18,053
2	516,973	441,633	617,729	1,059,362	78,425	980,937
3	496,361	968,112	648,886	1,616,998	410,289	1,206,709
4	1,543,737	205,661	85,465	291,126	73,535	217,591
Total	2,936,193	1,623,719	1,394,873	3,018,592	595,302	2,423,290
Alternative C						
1	378,356	8,839	43,032	51,871	158,443	(106,572)
2	520,896	441,632	613,806	1,055,438	254,046	801,392
3	412,917	935,608	764,834	1,700,442	480,214	1,220,228
4	1,488,067	208,834	137,961	346,795	929,445	(582,650)
Total	2,800,236	1,594,913	1,559,633	3,154,546	1,822,148	1,332,398
Alternative D						
1	377,690	9,058	43,480	52,538	243,597	(191,059)

Reach	Damages	Benefits, 2040-2089	Benefits, 2090 -2140	Total Benefits	Cost	Net Benefits
2	513,925	441,644	620,765	1,062,409	571,451	490,958
3	385,153	934,090	794,116	1,728,206	762,370	965,836
4	1,484,098	212,878	137,886	350,764	1,293,505	(942,741)
Total	2,760,866	1,597,670	1,596,247	3,193,917	2,870,923	322,994
Alternative E						
1	7,566	338,392	84,270	422,662	4,476,963	(4,054,301)
2	5,422	872,866	698,046	1,570,912	5,649,920	(4,079,008)
3	91,219	1,184,823	837,317	2,022,140	5,998,613	(3,976,473)
4	51,478	1,555,588	227,796	1,783,384	5,568,938	(3,785,554)
Total	155,685	3,951,669	1,847,429	5,799,098	21,694,434	(15,895,336)
Alternative F						
1	7,698	338,331	84,198	422,529	2,709,077	(2,286,548)
2	5,532	872,791	698,011	1,570,802	10,310,908	(8,740,106)
3	154,799	1,114,885	843,675	1,958,560	4,794,508	(2,835,948)
4	1,583,793	147,784	103,286	251,070	1,409,502	(1,158,432)
Total	1,751,822	2,473,791	1,729,170	4,202,961	19,223,995	(15,021,034)
Alternative G						
1	7,566	338,392	84,270	422,662	1,477,886	(1,055,224)
2	5,532	872,791	698,011	1,570,802	3,995,985	(2,425,183)
3	836,737	994,949	281,674	1,276,623	2,635,903	(1,359,280)
4	1,739,360	82,868	12,634	95,502	2,184,621	(2,089,119)

Reach	Damages	Benefits, 2040-2089	Benefits, 2090 -2140	Total Benefits	Cost	Net Benefits
Total	2,589,195	2,289,000	1,076,589	3,365,589	10,294,395	(6,928,806)

Table A-32: NED Evaluation, High RSLC ($1,000s, PV)

Reach	Damages	Benefits, 2040-2089	Benefits, 2090 - 2140	Total Benefits	Cost	Net Benefits
FWOP						
1	1,588,652					
2	7,849,737					
3	9,517,445					
4	3,634,010					
Total	22,589,844					
Alternative B						
1	965,019	320,645	302,988	623,633	199,761	423,872
2	3,912,400	2,954,739	982,598	3,937,337	602,419	3,334,918
3	4,311,573	3,742,436	1,463,436	5,205,872	1,445,989	3,759,883
4	2,652,393	559,020	422,597	981,616	307,241	674,375
Total	11,841,385	7,576,840	3,171,619	10,748,458	2,555,410	8,193,048
Alternative C						
1	1,580,163	242,517	(234,028)	8,489	158,443	(149,954)
2	7,506,866	2,823,902	(2,481,032)	342,870	254,046	88,824
3	8,308,682	3,245,086	(2,036,323)	1,208,763	480,214	728,549
4	3,479,951	636,362	(482,303)	154,059	929,445	(775,386)
Total	20,875,662	6,947,867	(5,233,686)	1,714,181	1,822,148	(107,967)
Alternative D						
1	1,586,766	250,491	(248,605)	1,886	243,597	(241,711)

Reach	Damages	Benefits, 2040-2089	Benefits, 2090 - 2140	Total Benefits	Cost	Net Benefits
2	6,539,669	2,871,974	(1,561,906)	1,310,068	571,451	738,617
3	7,478,140	3,330,010	(1,290,705)	2,039,305	762,370	1,276,935
4	3,086,263	624,576	(76,829)	547,747	1,293,505	(745,758)
Total	18,690,838	7,077,051	(3,178,045)	3,899,006	2,870,923	1,028,083
Alternative E						
1	434,452	629,372	524,828	1,154,200	4,646,090	(3,491,890)
2	556,059	4,038,925	3,254,752	7,293,678	5,985,951	1,307,727
3	807,670	5,340,475	3,369,300	8,709,775	6,345,109	2,364,666
4	355,028	2,302,578	976,403	3,278,982	5,788,219	(2,509,237)
Total	2,153,209	12,311,350	8,125,283	20,436,635	22,765,369	(2,328,734)
Alternative F						
1	143,882	628,371	816,399	1,444,770	2,717,876	(1,273,106)
2	265,043	4,072,426	3,512,267	7,584,693	10,318,477	(2,733,784)
3	891,773	5,342,893	3,282,779	8,625,672	5,444,607	3,181,065
4	1,983,223	676,750	974,037	1,650,787	2,155,563	(504,776)
Total	3,283,921	10,720,440	8,585,482	19,305,922	20,636,523	(1,330,601)
Alternative G						
1	247,125	629,371	712,156	1,341,527	1,523,273	(181,746)
2	293,399	4,038,724	3,517,614	7,556,338	4,016,810	3,539,528
3	3,211,672	4,822,057	1,483,717	6,305,774	3,051,726	3,254,048
4	2,488,744	416,542	728,723	1,145,265	2,536,484	(1,391,219)

Reach	Damages	Benefits, 2040-2089	Benefits, 2090 - 2140	Total Benefits	Cost	Net Benefits
Total	6,240,940	9,906,694	6,442,210	16,348,904	11,128,293	5,220,611

The NED plans under each RSLC curve are shown in **Table A-33**.

Table A-33: NED Plan Under Each RSLC Curve

USACE RSLC Curve	NED Plan
Low	A – No Action
Intermediate	B
High	G

A-8.3 Lessons Learned from NED Analysis of Alternatives

As described earlier, the plan formulation strategy included varied scales and phasing of risk reduction measures within the alternatives to provide insight into the best approach to manage the study area risk under uncertain timing. The following are some of the lessons learned over the course of the initial analysis of the focused array of alternatives:

- SLC is the main driver of inundation risk over the study period. The initial engineering suggested that this would be the case due to the relatively small contribution of storm surge to the total water level in storm events, and G2CRM modeling confirmed this. The interfacing of the storm suite and the economic asset inventory suggested that there is existing risk to the study area from infrequent storm events, but the predominant flood risk comes from SLC, which makes infrequent events today a monthly or daily occurrence in the future.
- Aligning costs and benefits in time helps to maximize net NED benefits. This refers to discounting future costs to adapt proposed solutions to future SLC. While it may seem efficient to build higher in one phase to have flood risk reduction measures in place for the future, the analysis demonstrated that building to 15.5 feet or even 19 feet in the initial years is only justified by offsetting risks that occur much later in the study period, if at all. If possible, building to a lower level and then raising the crest elevation when risk increases would be the optimal approach in response to both present and future flood hazards. However, other factors such as constructability, disruption, community acceptability, and environmental impacts must also be weighed as part of the formulation decision under the total benefit framework.
- The White House Office of Management and Budget recently published Circular A-4 which suggests using declining discount rates over a long POA could impact the analysis above as this feasibility study advances. Circular A-4 states:

  > *"Special ethical considerations arise when comparing benefits and costs across Generations... Future citizens and residents who are affected by such choices cannot take part in making them, and today's society must act with some consideration of their interest... [G]overnment should treat all generations equally..."*

"A distinct reason for discounting the benefits and costs accruing to future generations at a lower rate is uncertainty about the appropriate value of the discount rate... Private market rates provide a reasonably reliable reference for determining the rate at which society is willing to trade consumption over time within a few decades, but for extremely long time periods no comparable private rates exist. Because future changes in the social rate of time preference are uncertain but correlated over time, the certainty-equivalent discount rate will have a declining schedule... The appropriate discount rate declines because it is the average of the cumulative discount factors, not an average of the discount rates, that matters."

- Overtopping of a measure leads to catastrophic damages as compared to the FWOP condition damages. Building a measure shifts damages later in time by preventing near- and medium-term damages, but the reduction in hazard means assets don't take protective actions (floodproofing/retreat). Hence, when overtopping occurs, it is in a floodplain with many vulnerable assets. Moreover, the water levels are much higher because the coastal defense measure has allowed water to build up behind it; when overtopping occurs, water levels are much higher at the first-floor elevation of the asset. This leads to much higher damages. Preventing overtopping or retreating once the measure is expected to be overtopped will provide more opportunities to maximize net NED benefits.
- The NED seismic benefits, which stem from changes to the existing OMRR&R costs of the extant coastal infrastructure between the FWOP and the FWP, constitute a smaller part of the benefits pool under the High SLC curve but a larger part of the benefits pool under the Intermediate and Low curves. This is because those benefits differ only marginally by SLC curve. Note that other "seismic benefits" (outside of the risk to the existing coastal infrastructure) have not been calculated in the NED account to avoid conflict and duplication through the treatment of project costs per WRDA 2020, Section 152, as amended. These benefits are instead qualitatively or semi-quantitatively defined within the OSE account, detailed below.
- In parallel with implementation considerations, identification of the TSP must also recognize the incremental cost associated with raising the level of protection. Due to the high level of investment below ground to stabilize seismically unstable soils, the incremental cost of increasing crest elevation may factor into plan refinements at a later stage. The PDT considered options where smaller-scale measures were built without doing ground improvement but were instructed by the Vertical Team that anything that was built in a seismic region would need to meet USACE seismic codes (meaning plans without ground improvement would not meet the P&G's Acceptability criterion).

- Measures that may cost effectively reduce risk but are more likely to face serious opposition thereby posing a schedule risk. Alternative F was deemed unacceptable by the PDT in Reaches 3 and 4. Alternative F uses water management structures across the two creeks (Mission and Islais) and the NFS was concerned that these structures would impact HTRW sites, create water quality concerns and opposition from regulatory agencies and run into serious public opposition. These measures would also rely on an actively managed flood defense with potential concern about deployment and reliability while placing a high OMRR&R burden on the NFS. The NFS expressed particular concern about the earthquake reliability of mechanical structures creating heightened risk associated with a single point of failure. Despite Alternative F having the highest net NED benefits of any measure under the High curve in Reach 3 and being competitive with nonstructural in Reach 4, Alternative F was screened from consideration at this point.

Section A-9. Final Array of Alternatives

As discussed in the previous section, the evaluation of the focused array of alternatives was conducted waterfront-wide by combining the NED costs and benefits for each of the four reaches. **Table A-34** shows the features of the alternative plans in the final array. The alternative plans in the final array were evaluated against all four P&G accounts (NED, RED, OSE, and EQ) to develop a Total Net Benefits Plan (TNBP) to maximize net benefits across all benefit categories, as required by the January 5, 2021, Policy Directive Comprehensive Documentation of Benefits in Decision Document.

Alternative F was carried forward because the benefits and impacts were too close to screen from further consideration based on the level of analysis completed during the focused array phase. The alternative warranted further consideration. Alternatives A, B and G were carried forward as cost effective plans that were the NED plan for the 3 RSLC scenarios. The final array also includes Independent Measures for Consideration, which are further described in section A-11.5.5.

Table A-34: Final Array Features Summary

<table>
<tr><th>Alternative</th><th>2040 - 2089</th><th>2090 - 2140</th></tr>
<tr><td>A – No Action</td><td></td><td></td></tr>
<tr><td rowspan="2">B – Nonstructural

Variant 1: USACE Intermediate Curve

Variant 2: USACE High Curve</td><td colspan="2">Retreat assets exposed to the monthly coastal flood
Floodproof (perimeter walls + dry floodproofing) assets exposed to 1% AEP coastal flood</td></tr>
<tr><td><u>2040</u>
Retreat:
Floodproof:

<u>2065</u>
Retreat:
Floodproof:</td><td><u>2090</u>
Retreat:
Floodproof:

<u>2115</u>
Retreat:
Floodproof:</td></tr>
<tr><td>F – Manage the Water, Scaled for Higher Risk

LOD primarily along existing shoreline (15.5’ NAVD88, adapts to 19’)
• <u>more shoreline extension</u> into Bay in R1,2
• <u>retreat</u> mostly on piers in R4</td><td>Naturalized or embankment shorelines earthen & paved (R3,4)
Floodwalls (R1)
Seawalls/bulkhead walls
• w Fill (R1,2,3) – larger shoreline extension compared to E
• w/o Fill (R4)
• at Ferry Building, seawall further bayward of bldg.
Ground improvements
Water mgmt. structure (tide gates) (R3,4)
Ecological armoring (R4)
Ecotone levee (R4)
Perimeter walls on piers (R1,2,3)
Raised/rebuilt wharves (R3 - South Beach Harbor only)
Floodproof buildings <25
Elevated buildings <20
Demo buildings <15
Inland drainage modifications</td><td>3.5’ vertical extension (wall or added naturalized or embankment shoreline height) added to naturalized or embankment shoreline crests, floodwalls, and seawalls (R1,2,3,4)
Ground improvements (R4 – where LOD moved further inland)
Water mgmt. structure (permanently close the tide gates, add pumps) (R3,4)
Ecotone levee with coarse beach (R3)
Ecological armoring (R4)
Wetland preservation and restoration (R4)
Raised/rebuilt wharves (R3 - South Beach Harbor only)
Demo buildings >45</td></tr>
</table>

Alternative	2040 - 2089	2090 - 2140
G – Align with Watersheds, Scaled for Higher Risk *LOD primarily along existing shoreline (15.5-17' NAVD88, adapts to 19)* • *little/no shoreline extension* • *more retreat in R4, esp. by 2090*	Naturalized or embankment shorelines* earthen & paved (R3,4) Floodwalls (R1,3,4) Seawalls/bulkhead walls • little/no fill (R1,2,3) • *at Ferry Building, seawall along landside edge of bldg.* Ground improvements Elevated bridges • 3rd Street Bridge (R3) • 4th Street Bridge (R3) • Illinois Street Bridge (R4) Ecological armoring (R4) Ecotone levee (R4) Wetland preservation and restoration (R4) Perimeter walls on piers (R1,2,3) Raised/rebuilt wharves (R1,2,3) Floodproof buildings >45 Elevated buildings <20 Demo buildings <15 Inland drainage modifications	2'-3.5' vertical extension (wall or added naturalized or embankment shoreline height) added to naturalized or embankment shoreline crests, floodwalls, and seawalls (R1,2,3,4) Retreat some areas adjacent to creeks and construct new inland naturalized or embankment shorelines and floodwalls (R3,4) Ground improvements (R3,4) Wetland preservation and restoration (R3,4) Demo bridge (R4 – Illinois Street Bridge) – due to retreat of adjacent area Demo buildings >50

Section A-10. Evaluation of the Final Array

Typical feasibility studies identify a NED plan by reasonably maximizing net NED benefits and considering the P&G criteria and performance differences across RED, OSE, and EQ benefit accounts.

Recent policy guidance formally requires identification of a plan that reasonably maximizes total net benefits across all four accounts. In response, the PDT developed a framework for evaluating alternative plans in a total benefits context. Key portions of the process and evaluation are presented here, and a summary of the findings is presented in subsequent sections.

The complexity of the analysis, uncertainty of RSLC timing and scaling, and the compounding complication of factors such as seismic risk, necessitated the development of a framework to guide the analysis and PDT formulation of its recommendations. The process to evaluate the final array and identify a TNBP can be described in three steps:

- Step 1: Evaluate the Final Array
- Step 2: Compare the Final Array
- Step 3: Develop the TNBP

For the first step, Evaluate the Final Array, the PDT applied considerable effort to thoroughly define quantifiable metrics to correlate to the specific study objectives to support decision making in response to this policy. Most of the EQ and OSE benefits are not quantified in dollars, thus the criteria were developed to explore performance differences across plans and to support the developing practice.

The PDT quantitatively and/or qualitatively characterized NED, RED, OSE, and EQ benefits at three RSLC rates, by geographic reach wherever possible. This effort was taken to support the development of reach-level recommendations that would allow selecting the geographic reaches that performed the best for various RSLC scenarios from among the various alternatives in the Final Array.

This large array of metrics was defined to support evaluation and comparison across alternatives but was reduced to a subset of key decision drivers once the quantification was completed. Comparison of the metrics across alternatives illustrated that many did not show meaningful differences and would not influence plan selection, and thus were deleted to streamline the matrix management. Some were informative but did not reflect priority study purposes and were also deleted from the matrix but referenced for descriptive purposes where appropriate.

For the second step, Compare the Final Array, the PDT used a Total Benefits (TB) matrix with key decision drivers described above, including summaries of findings for each alternative by reach and RSLC. During this step, the impacts of over-investment and under-investment was analyzed by examining the robustness of each alternative under each RSLC scenario, lead times for subsequent adaptation actions, and coastal life safety and seismic performance. This analysis was referred to as ”regret” analysis, since decisions to defer cost until increasing risk is evident may preclude some adaptation choices due to their necessary lead time.

For the third step, Identify the TNBP, the PDT developed an approach to heat-mapping the results to support identification of the TNBP, by reach, as further described below.

As described earlier in the plan formulation strategy, the alternatives were designed to address a target height of the dominant risk of higher water surface elevations as RSL rises. This formulation strategy was applied to provide insight about cost-effective performance of plans across time under uncertain risk.

The first comparison of the TB matrix confirmed several relatively intuitive expectations of plan performance and introduced a less obvious insight. NED benefits, which primarily consist of damages avoided, vary as exposure to flood risk is reduced. NED and RED damages are damages avoided and business and regional activities that are disrupted following a flood event.

All metrics vary based on exposure to flood risk, or in other words, metrics vary across alternative depending on whether assets are located inside or outside of the LOD. Meaningful differences of metrics across alternatives were evident in benefit metrics that are not correlated with the NED benefits, which primarily consist of damages avoided.

Identification of a TNBP required multiple rounds of analysis of plan performance and refinements to identify a plan that best addresses uncertain timing of risk over the POA.

The resulting range of multiple scales of actions that can address increasing risk over the POA is a resilience strategy, and the resulting TNBP is a subset of those actions that can be constructed in the near term and adapted as appropriate.

The TB matrix measured the four benefit accounts based on exposure to flood hazard and informed the relative performance of plan components and comparison of alternative plans. The factors that led to selecting the TNBP by reach for each RSLC and the timing of investments to produce benefits and accept tradeoffs were seismic life safety, historical district preservation, concerns with acceptability, and preservation of maritime activity.

A-10.1 Total Benefits Evaluation

The evaluation of the focused array presented in **Section A-8** specifically evaluated NED benefits, which stem from:

- preventing retreat, preventing inundation losses
- protecting the various existing networks in the study area (SFMTA, SFPUC, and the existing coastal defense system)

RED, OSE, and EQ benefits are discussed comprehensively in *Appendix E*: *Economic and Social Considerations*. This section describes how these categories were evaluated comprehensively as part of a total benefits evaluation.

A-10.1.1 Regional Economic Development

RED impacts were described as business economic disruptions (direct, indirect, and induced output loss) and employment losses (described as the number of full-time equivalent jobs lost). Additionally, transportation and industrial revenue loss were calculated for some of the major transportation and industrial systems within the study area. These benefits were calculated in the FWOP and the FWP across all three USACE SLC curves.

Direct Damages: Methodologically, the PDT created unique depth-percent damage curves that represent the business interruption incurred by businesses in the study area. These curves were created using HAZUS' business interruption metrics, which show how long a business will be offline based on the depth of flooding above the first-floor elevation. These curves were linked to the commercial and industrial assets within the asset inventory (the creation of which is documented in Section 3). These curves are used in G2CRM. However, to ensure that the dynamic inventory works properly, the damages are counted as "content" damages while the "structure" damages are maintained as they are in the NED G2CRM inventory. This ensures consistency between the assumptions in the NED G2CRM modeling and the RED G2CRM modeling.

Indirect/Induced Damages: The direct damages calculated within G2CRM are then put into IMPLAN. IMPLAN is an input-output (IO) software used to quantify the indirect and induced consequences these direct impacts have on jobs and economic output considering the larger California economy. It is described in more detail in the Regional

Economic Development Report within Appendix E, Economic and Social Considerations.

A-10.1.2 Other Social Effects

The OSE metrics were broken down into five overarching categories:

- Health and Safety
- Economic Vitality
- Social Connectedness
- Community Identity
- Social Vulnerability and Resiliency

The PDT developed metrics to capture potential impacts across these five broad categories in response to the policy directive that all four benefit accounts be considered in plan selection. Some effects were small and did not end up influencing the decision, but the PDT did not pre-suppose the benefit categories prior to benefit computation.

Many OSE benefits could be broken down into three different types of computation: exposure impacts, proximity to HTRW, and income or cost impacts measured in dollars.

A-10.1.3 Environmental Quality

The EQ metrics were developed in two categories:

- Physical Environment
- Biological Environment

The metrics under the physical environment reflect changes that would result from the implementation of the project., including HTRW contaminated sites, carbon sequestration, water quality, and reduced wave runup through EWN. The metrics under biological environment capture impacts to habitats and Threatened and Endangered Species. The metrics were not measured in dollars and supported consideration of broader benefits. The EQ benefits did not vary significantly across alternative plans and did not justify any plan over another, although the EWN measures were shown to contribute EQ streams over time.

A-10.2 Decision Drivers

As described previously, the USACE evaluation process now includes the comprehensive documentation of all benefits as part of the decision-making process and the identification of a TNBP. A key consideration was to identify the metrics that would drive decision-making and comparative analysis. After the quantification of the RED, OSE, and EQ metrics, the PDT created a “decision drivers” matrix to help visualize the metrics by plan, reach, and SLC curve. The decision drivers matrix included only a subset of the RED and OSE metrics quantified. Working with a smaller number of metrics was assumed to simplify decision making, but the PDT did not want to cull metrics arbitrarily. Metrics were removed from consideration for a variety of reasons:

- The metric didn't change between the FWOP and any of the FWP conditions. This occurred when the damage arose outside the LODs (meaning there would be no change from the FWOP to the FWP) or if there were no damages seen in the FWOP or FWP (for instance, maritime losses were considered but were minimal in the FWOP, meaning there could be no significant difference in the FWP).
- The metric was determined to not be as important as other metrics to the NFS or PDT. This was not possible to determine before seeing the FWOP and FWP impacts. However, in some cases, the PDT could say that the difference in impacts was not worth justifying a tradeoff of NED benefits or project performance. For example, the RED metrics, while critically important to those who suffer RED losses, were determined to not support robust decision making, although they were imperative for describing the FWOP and FWP conditions.

Within the decision drivers matrix, individual cells were shown with a color and a number to show the comparative value for each metric under each alternative under each SLC curve. This was purely to allow for a simplified evaluation of metrics at a glance; robust decision-making requires a deeper understanding of these impacts and the comparison provides information for overall performance to the decision maker. The Economics team facilitated conversations with the full PDT about how to assess performance across the metrics to consider in development of a TNBP in combination with additional information (actual magnitude of effects, when impacts would be expected, etc.) to support the use of the matrices. The colors and numbers, then, allow the viewer to see where plans differ, but that is not a sufficient condition to making a decision.

The final decision drivers are presented in Table A-35.

Table A-35: Decision Drivers

Category	Items	Metric
NED Account		
Benefits	FWOP Minus Residual Risk	Dollars ($)
Costs	Total Construction Cost	$
Efficiency	BCR	BCR
Return on Investment	Net Benefits	$
Residual Damages	Residual Damages	$
RED Account		
Business Economic Disruptions	Reduced Business Disruption Benefits	$
OSE Account		

Health and Safety	Coastal Life Safety Risk (Overtopping)	Score/Ranking Scheme
	Seismic Life Safety Risk and Resilience	Score/Ranking Scheme
Economic Vitality	Job Protection	Variance from FWOP
	Maritime Metrics	Score/Ranking Scheme
Social Connectedness	Public Transit Mobility	Score/Ranking Scheme
Community Identity	Community and Cultural Assets	Assets (number)
	Historic Asset and District Designation	Score/Ranking Scheme
Social Vulnerability and Resiliency	Vulnerable Population Exposure	People (number)/Score
	Disproportionate Effects on Vulnerable Communities	Score/Ranking Scheme
	Permanently Displaced Population	People (number)
	Compromised Disaster Response Sites	Sites (number)
	Affordable Housing	Affordable Housing Units (number)
EQ Account		
Physical Environment	HTRW Contaminated Sites	% Exposure Reduced
	Carbon Sequestration	MTCO2e
	Water Quality	Score/Ranking Scheme
	Wave Runup Reduction (EWN)	Linear Feet
Biological Environment	NNBF	Acres
	Threatened and Endangered Species	Species Benefited (number)

A-10.3 Total Benefits Matrix

For each RSLC, a TB matrix was created to capture the multiple benefits across NED, RED, OSE, and EQ accounts to support evaluation of the alternatives against study objectives at the plan level and at the individual reach level. **Table A-36** displays the TB matrix using the USACE Low RSLC scenario. **Table A-37** through **Table A-40** display the TB matrix using the USACE Intermediate RSLC scenario; and **Table A-41** through **Table A-43** display the TB matrix using the USACE High RSLC scenario. The multiple benefits were numerically scored in units appropriate to the metric, and color coded. Green, orange and yellow cells reflect whether the alternative performed better, worse, or not meaningfully different, respectively, from other alternatives in that metric. For three metrics, shades of green, red, and orange were used to further distinguish relative performance. Reduced Business Disruption metric used dark and light green, yellow, peach and berry o compare plans. For Job Access and Maritime metrics, light green and berry were used to compare plans. The relative differences across plans were applied to support plan comparisons and tradeoffs as a deliberative tool, not a deterministic tool.

Table A-36: Waterfront-Wide, Low RSLC Curve, Total Benefits Matrix

Category	Items	Alt B	Alt C	Alt D	Alt E	Alt F	Alt G
RED Account							
Business Economic Disruptions	Reduced Business Disruption Benefits						
OSE Account							
Health and Safety	Coastal Life Safety Risk (Overtopping)						
	Seismic Life Safety Risk & Resilience						
	Compromised Disaster Response Sites						
Economic Vitality	Job access						
	Maritime						
Social Connection	Public transit mobility						
Community Identity	Community and Cultural Assets						
Social Vulnerability and Resiliency	Vulnerable Population Exposure						
	Disproportionate effects on vulnerable communities						
	Permanently Displaced Population						
	Affordable Housing Exposed						
EQ Account							
Physical Environment	HTRW Contaminated Sites						
	Carbon Sequestration						
	Water Quality						
	EWN to reduce wave runup						
Biological Environment	Habitat (NNBF)						
	Threatened and Endangered Species						

Table A-37: Reach 1, Intermediate RSLC Curve, Total Benefits Matrix

Category	Items	Alt B	Alt C	Alt D	Alt E	Alt F	Alt G
RED Account							
Business Economic Disruptions	Reduced Business Disruption Benefits						
OSE Account							
Health and Safety	Coastal Life Safety Risk (Overtopping)						
	Seismic Life Safety Risk & Resilience						
	Compromised Disaster Response Sites						
Economic Vitality	Job Access						
	Maritime Metrics						
Social Connection	Public transit mobility						
Community Identity	Community and Cultural Assets						
Social Vulnerability and Resiliency	Vulnerable Pop Exposure						
	Disproportionate effects on vulnerable communities						
	Permanently Displaced Population						
	Affordable Housing						
EQ Account							
Physical Environment	HTRW Contaminated Sites						
	Carbon Sequestration						
	Water Quality						
	EWN to reduce wave runup						
Biological Environment	Habitat (NNBF)						
	Threatened and Endangered Species						

Table A-38: Reach 2, Intermediate RSLC Curve, Total Benefits Matrix

Category	Items	Alt B	Alt C	Alt D	Alt E	Alt F	Alt G
RED Account							
Business Economic Disruptions	Reduced Business Disruption Benefits						
OSE Account							
Health and Safety	Coastal Life Safety Risk (Overtopping)						
	Seismic Life Safety Risk & Resilience						
	Compromised Disaster Response Sites						
Economic Vitality	Job Access						
	Maritime Metrics						
Social Connection	Public transit mobility						
Community Identity	Community and Cultural Assets						
Social Vulnerability and Resiliency	Vulnerable Pop Exposure						
	Disproportionate effects on vulnerable communities						
	Permanently Displaced Population						
	Affordable Housing						
EQ Account							
Physical Environment	HTRW Contaminated Sites						
	Carbon Sequestration						
	Water Quality						
	EWN to reduce wave runup						
Biological Environment	Habitat (NNBF)						
	Threatened and Endangered Species						

Table A-39: Reach 3, Intermediate RSLC Curve, Total Benefits Matrix

Category	Items	Alt B	Alt C	Alt D	Alt E	Alt F	Alt G
RED Account							
Business Economic Disruptions	Reduced Business Disruption Benefits						
OSE Account							
Health and Safety	Coastal Life Safety Risk (Overtopping)						
	Seismic Life Safety Risk & Resilience						
	Compromised Disaster Response Sites						
Economic Vitality	Job Access						
	Maritime Metrics						
Social Connection	Public transit mobility						
Community Identity	Community and Cultural Assets						
Social Vulnerability and Resiliency	Vulnerable Pop Exposure						
	Disproportionate effects on vulnerable communities						
	Permanently Displaced Population						
	Affordable Housing						
EQ Account							
Physical Environment	HTRW Contaminated Sites						
	Carbon Sequestration						
	Water Quality						
	EWN to reduce wave runup						
Biological Environment	Habitat (NNBF)						
	Threatened and Endangered Species						

Table A-40: Reach 4, Intermediate RSLC Curve, Total Benefits Matrix

Category	Items	Alt B	Alt C	Alt D	Alt E	Alt F	Alt G
RED Account							
Business Economic Disruptions	Reduced Business Disruption Benefits						
OSE Account							
Health and Safety	Coastal Life Safety Risk (Overtopping)						
	Seismic Life Safety Risk & Resilience						
	Compromised Disaster Response Sites						
Economic Vitality	Job Access						
	Maritime Metrics						
Social Connection	Public transit mobility						
Community Identity	Community and Cultural Assets						
Social Vulnerability and Resiliency	Vulnerable Pop Exposure						
	Disproportionate effects on vulnerable communities						
	Permanently Displaced Population						
	Affordable Housing						
EQ Account							
Physical Environment	HTRW Contaminated Sites						
	Carbon Sequestration						
	Water Quality						
	EWN to reduce wave runup						
Biological Environment	Habitat (NNBF)						
	Threatened and Endangered Species						

Table A-41: Reach 1, High RSLC, Total Benefits Matrix

Category	Items	Alt B	Alt C	Alt D	Alt E	Alt F	Alt G
RED Account							
Business Economic Disruptions	Reduced Business Disruption Benefits						
OSE Account							
Health and Safety	Coastal Life Safety Risk						
	Seismic Life Safety Risk & Resilience						
	Compromised Disaster Response Assets						
Economic Vitality	Job Access						
	Maritime						
Social Connection	Public transit mobility						
Community Identity	Community and Cultural Assets						
	Historic Asset and District Designation						
Social Vulnerability and Resiliency	Vulnerable Pop Exposure						
	Disproportionate effects on vulnerable communities						
	Permanently Displaced Population						
	Affordable Housing Exposed						
EQ Account							
Physical Environment	HTRW Contaminated Sites						
	Carbon Sequestration						
	Water Quality						
	EWN to reduce wave runup						

Category	Items	Alt B	Alt C	Alt D	Alt E	Alt F	Alt G
Biological Environment	Habitat (NNBF)						
	Threatened and Endangered Species						

Table A-42: Reach 2, High RSLC Curve, Total Benefits Matrix

Category	Items	Alt B	Alt C	Alt D	Alt E	Alt F	Alt G
RED Account							
Business Economic Disruptions	Reduced Business Disruption Benefits						
OSE Account							
Health and Safety	Coastal Life Safety Risk						
	Seismic Life Safety Risk & Resilience						
	Compromised Disaster Response Assets						
Economic Vitality	Job Access						
	Maritime						
Social Connection	Public transit mobility						
Community Identity	Community and Cultural Assets						
Social Vulnerability and Resiliency	Vulnerable Pop Exposure						
	Disproportionate effects on vulnerable communities						
	Permanently Displaced Population						
	Affordable Housing Exposed						
EQ Account							
Physical Environment	HTRW Contaminated Sites						
	Carbon Sequestration						
	Water Quality						
	EWN to reduce wave runup						

Category	Items	Alt B	Alt C	Alt D	Alt E	Alt F	Alt G
Biological Environment	Habitat (NNBF)						
	Threatened and Endangered Species						

Table A-43: Reach 3, High RSLC Curve, Total Benefits Matrix

Category	Items	Alt B	Alt C	Alt D	Alt E	Alt F	Alt G
RED Account							
Business Economic Disruptions	Reduced Business Disruption Benefits						
OSE Account							
Health and Safety	Coastal Life Safety Risk						
	Seismic Life Safety Risk & Resilience						
	Compromised Disaster Response Assets						
Economic Vitality	Job Access						
	Maritime						
Social Connection	Public transit mobility						
Community Identity	Community and Cultural Assets						
Social Vulnerability and Resiliency	Vulnerable Pop Exposure						
	Disproportionate effects on vulnerable communities						
	Permanently Displaced Population						
	Affordable Housing Exposed						
EQ Account							
Physical Environment	HTRW Contaminated Sites						
	Carbon Sequestration						
	Water Quality						
	EWN to reduce wave runup						
Biological Environment	Habitat (NNBF)						
	Threatened and Endangered Species						

Table A-44: Reach 4, High RSLC Curve, Total Benefits Matrix

Category	Items	Alt B	Alt C	Alt D	Alt E	Alt F	Alt G
RED Account							
Business Economic Disruptions	Reduced Business Disruption Benefits						
OSE Account							
Health and Safety	Coastal Life Safety Risk						
	Seismic Life Safety Risk & Resilience						
	Compromised Disaster Response Assets						
Economic Vitality	Job Access						
	Maritime						
Social Connection	Public transit mobility						
Community Identity	Community and Cultural Assets						
Social Vulnerability and Resiliency	Vulnerable Pop Exposure						
	Disproportionate effects on vulnerable communities						
	Permanently Displaced Population						
	Affordable Housing Exposed						
EQ Account							
Physical Environment	HTRW Contaminated Sites						
	Carbon Sequestration						
	Water Quality						
	EWN to reduce wave runup						
Biological Environment	Habitat (NNBF)						
	Threatened and Endangered Species						

A-10.4 Total Net Benefits Plan

The TNBP was created by comparing performance of the alternative plans for each reach under each RSLC scenario and across the RSLC scenarios to assess the best series of actions to maximize benefits across all four accounts and meet the study objectives. Adaptability of the plan components over 100 years is the critical study consideration to ensure that a plan can best address risk under uncertain timing of RSLC. Although adaptation has been simplified to reflect implementation in 2090 to model the benefits and costs a MAP will be developed to define risk triggers to clarify the appropriate scale, alignment and timing of the adaptation. This resiliency requirement drives the TNBP to include multiple potential adaptations to address many potential risk scenarios over the study period. The TNBP was formulated as a Resilience Strategy, to create a continuum of potential plan adaptations to a changing risk scenario.

The TNBP can differ from the NED plan due to:

- Maximizing net benefits across the four accounts
- Holistic approach to multiple hazards along the waterfront, and multiple Federal agency missions
- Emphasis on adaptation planning (selecting alternatives for their overall ability to function with next actions in mind)
- Early impact analysis and feedback from City agencies
- Regulatory risks to permitting, construction, and cost

As noted earlier, the NED plan is selected by subtracting the costs of the alternatives from the NED benefits by alternative to find which plan has the highest net benefits. Identification of the TNBP is not as straightforward. The Jan 5, 2021, Policy Directive Comprehensive Documentation of Benefits in Decision Document states the need to determine *"a plan that maximizes net total benefits across all benefit categories,"* but because benefits are non-monetary while the costs remain monetary, they cannot simply be subtracted from each other to determine the net total benefits plan. Additionally, these metrics must be considered across the various RSLC curves.

A-10.4.1 The TNBP Development Process Simplified

The TNBP was developed by considering available benefits in a three-step process to assess efficient flood risk reduction under uncertain timing of risk and to assess tradeoffs of net NED benefits to achieve more benefits across other benefit categories that are consistent with stated study objectives. The three steps that incrementally analyzed available tradeoffs were:

1) Consider what plan features would maximize NED benefits without a specified RSLC scenario
2) Consider overall value of higher net benefits (correlated with) NED based on alignment: Provide risk management to greater study area population and

achieve OSE benefits to offset the loss of net NED benefits as cost of alternative increases.

3) Consider justification of specific tradeoffs in timing or actions to achieve benefits that are not correlated with NED benefits: Greater investment earlier in Reach 2 and Reach 4 to avoid disruptions and achieve OSE benefits consistent with Study objectives.

The tradeoffs and rationale for the tradeoffs in each of the three steps are summarized below.

A-10.4.1.1 TNBP Efficiency Under Uncertain RSLC Scenario

One dominant theme in the TNBP choices of measures that differ from the NED scale within each reach is the need that the TNBP effectively manage risk across multiple possible RSLC scenarios over the POA. The NED scales were determined by assessing effectiveness of the plan measures and alignments under one specific RSLC scenario. To develop a TNBP that performs well under all RSLC scenarios means that it will not perform as well as optimized plan under any one RSLC scenario. The TNBP achieves positive net NED benefits under all RSLC scenarios, despite not maximizing net NED benefits under any single RSLC scenario.

This results in comparatively higher costs of the TNBP in several comparisons, but it also makes the TNBP perform consistently better than the NED scale plans across multiple RSLC scenarios.

The first action was selected to ensure flood risk is reduced without over-investment in initial years. The total net benefits and adaptive capacity of the first action were also a key consideration in the measure selection. In areas where there was little immediate flood risk, a scaled down version of nonstructural measures would reduce risk to structures and contents. In areas with high potential for multiple, non-monetized benefit streams proactive investment in larger coastal flood risk management alternatives are recommended. The leading reasons for these are:

- RED and OSE benefits correlated with flood risk may support Alternative E in the Southern Waterfront because its alignment is more bayward than Alternative G and, as such, it provides risk reduction for more assets, land, and people.
- Nonstructural alternatives prevent physical damage but do an incomplete job of preventing RED and OSE losses that may stem from disruption of regional infrastructure and services. This may support structural instead of nonstructural first actions in Reaches 1 and 4.
- Flooding may impact residents of vulnerable communities in Reach 4 who live and work around Pier 94-96 and Heron’s Head in ways that a nonstructural action won’t address. Disadvantaged communities are less resilient to these impacts, which may “multiply” the impact of the disruption impact discussed above.

- Seismic concerns in all four Reaches may support replacement of wharves, providing life safety benefits and extending the life of some culturally significant landmarks. Replacing wharves also presents the opportunity to preserve maritime berths across the waterfront.
- Resiliency concerns in all four Reaches may support larger construction earlier in the project timeframe, ensuring that measures are resilient throughout the POA. This is the opposite of lining up costs and benefits in time.
- Disaster response assets may not function in areas where nonstructural solutions are chosen. In Reach 4, there are disaster response assets that will face vulnerability in 2040, including assets located by Piers 92 and 94-96 by Islais Creek and Heron's Head Park.
- Major disruptions from construction problems should be avoided if possible. One way to do this is by building adaptable structures or building resilient structures that provide sufficient defense regardless of SLC curve. This is particularly important in Reach 2, where the Embarcadero, a major transportation corridor, will be impacted by construction.

Seismic improvements for any structural component of an alternative, irrespective of the risk of SLC or finished elevation of the measure, to comply with ER 1110-2-1806. Seismic design of study measures requires disturbance of larger portions of the study area and cost considerably more than non-seismic designs. Lower initial scales of measures could be constructed without the necessary soil improvements and seismic design, but later adaptations for increasing coastal flood and life safety risk would require the seismic design upgrades.

As a result, the PDT selected higher cost alternatives for distinct reaches in the TNBP based on risk, disruption, costs, and benefits. It was determined to be more cost-effective and justifiable to incur higher initial costs than to delay the expense to account for seismic improvements until adaptation of structural measures required upgrades to include seismic design. The PDT also determined some reaches had a greater benefit from the higher up-front costs of one alternative over another. For example, Alternative D would have managed flood risk in Reach 2 under low and intermediate RLSC scenario. Since the RSLC scenario and resulting risk is uncertain, if the midpoint adaptation requires increased height to perform under the High RSLC scenario, Alternative G was selected as the first action to avoid unnecessary disruption. As shown below, Alternative D is comparable to the seismic costs of Alternative G but Alternative G provides greater benefits and advantages. Alternative G:

- Requires no future disruption to protect against the RSLC scenario on the intermediate or high curve.
- Ensures robust protection for underground transit network critical to both local and regional mobility.

- Preserves historic resources contributing to the Embarcadero Historic District that would be lost with Alternative D, by replacing aging bulkhead walls and wharves expected to fail before the Alternative D (2090) second action.
- Maintains maritime access to piers and deepwater berths that are lost in Alternative D due to age and condition of existing bulkhead walls and wharves.
- Reduces life safety risk by installing a new seawall and new, seismically safe bulkhead wharves along heavily utilized public spaces and bulkhead buildings used as office, restaurants, and other publicly accessible venues.
- Utilizes measures suited to enjoyable public realm, open space, and visual access to the Bay.

A-10.4.1.2 Overall Value of Higher Net Benefits

A major takeaway from the decision drivers matrix is that many of the RED and OSE metrics are highly correlated with the NED inundation benefits because all RED and the majority of OSE metrics are also based on exposure to flooding.

When a strong correlation between NED, RED, and OSE benefits exists, a few generalizations can be made.

- If a measure has negative net NED benefits but provides relief from flooding, it is possible that the addition of RED/OSE benefits could still result in positive net total benefits (i.e., RED/OSE benefits can “compensate for” the negative net NED benefits).
- If two plans have equal, positive net NED benefits, the plan that provides more flood risk management will have higher RED and OSE benefits than the other, and it is likely that the higher flood risk management plan is the TNBP.
- If a plan has positive net NED benefits, it is even more defensible than it appears in the NED analysis because of the additive RED and OSE benefits.

The second observation above influenced the TNBP development. In the Southern Waterfront, Alternative G has higher net NED benefits than Alternative E, but Alternative G has a large amount of retreat in 2090. This implies Alternative E provides higher flood protection for those areas. In Reach 4, Alternative E and Alternative G have nearly equivalent net NED benefits, Alternative G providing slightly less than $100 million more than Alternative E has higher net total benefits. In Reach 3, Alternative G has over $400 million more net NED benefits than Alternative E; it worth it to sacrifice those net benefits (or, rather, incur the higher cost of Alternative E) to reap the additional RED and OSE benefits? That question is worth considering but is difficult to answer objectively; it should be kept in mind, though, as the analysis continues.

Another key takeaway relates to nonstructural versus structural solutions. Many of the RED and OSE metrics are based on exposure to risk. Structural measures typically address risk in the short term by removing the hazard but potentially leave communities vulnerable to overtopping or measure failure in the long term. Nonstructural measures, however, prevent the damage from exposure but does not prevent the disruption of flood events within the community. These disruptions are likely to be disproportionally experienced by less affluent communities, who often do not have the resources to mitigate these impacts (even if a nonstructural plan has prevented physical damage to assets in the community). As such, RED and OSE benefits may not be correlated with NED benefits for nonstructural plans, meaning a structural plan in Reach 1 or 4 may outperform the nonstructural first actions in terms of net total benefits.

A-10.4.1.3 Achieve Benefits Uncorrelated with NED

The analysis also considered metrics that were not correlated with the NED benefits.[6] The uncorrelated benefit categories may justify actions beyond the current actions determined in and altered through the correlation analysis (i.e., moving from Alternative G to Alternative E in Reaches 3 and 4), including using structural measures instead of nonstructural measures or building to higher crest elevation earlier in the POA.

Some of the metrics that are not correlated with flood risk are detailed below:

Seismic: Some seismic benefits can be found in the NED discussion of the existing coastal defense system, but there are seismic impacts to life safety in bulkhead buildings on wharves and in the waterfront areas. In the FWP, the reduction of these impacts is tied to whether the vulnerable wharf structures are replaced, especially along the Embarcadero. Projects that replace seismically vulnerable, aging waterfront structures with new, code compliant structures will inherently reduce the life-safety risk of waterfront assets. Additionally, the inclusion of substantial ground improvement in areas vulnerable to lateral spreading and liquefaction will reduce subsurface seismic hazards, thereby influencing the seismic performance of nearby structures. Alternatives C and D do not replace these wharves immediately (Alternative D does in 2090) while Alternatives E through G replace them in 2040. Whether the wharves are replaced will impact life safety and resilience.

Resiliency: A relevant factor for this study is that the adaptations to measures require time to come online. It is a concern that if a higher rate of SLC is realized, a new measure will take time to be constructed and that the residual risk during that period will result in high levels of damages. One way to ensure resiliency is to overbuild in the present so that when a higher risk is realized, there isn't the need to take another action that might be slow to be constructed.

EP 1100-2-1 Procedures to Evaluate Sea Level Change: Impacts, Responses, and Adaptation describes three approaches to addressing risks associated with sea level rise: anticipatory (precautionary), adaptive and reactive. Article 3 of the United Nations Framework Convention on Climate Change recommends that *"parties should take precautionary measures to anticipate, prevent, or minimize the causes of climate change and mitigate its adverse effects."* EP 1100-2-1 states that the major risk *"of large*

[6] Anticorrelation with NED benefits was also relevant. There were no RED or OSE benefits anticorrelated with the NED benefits, though some of the EQ metrics were. The PDT considered the EQ benefits "tiebreakers," since the effects were small in magnitude because the study area is small. As such, this appendix will not discuss how to handle decision making when a set of RED and OSE benefits are anticorrelated with NED benefits.

[precautionary] investments is that their future costs and benefits are functions of uncertain future sea levels: they may either provide less performance for less time than anticipated, or they may be constructed long before they are ultimately needed, leading to costs out of balance with performance.”

Precautionary investments can be warranted where they avoid impacts from multiple disruptions associated with adaptive management, where there are ancillary benefits of precautionary investments and where the lead time to design and construct subsequent actions is long.

Adaptation strategies (e.g., the 2nd action of Alternatives D-G) build in the potential for quick increases in crest elevation. However, the strategies that don’t retrofit existing structures but instead build new works may be slower.

Environmental Justice: Impacts to vulnerable communities in some cases will track with inundation. In Reach 4, however, where Alternative B is expected to buy down much of the risk of inundation, there is an argument to be made for investment in a structural solution earlier. Flood risk has multiple economic impacts on the community and its residents, and those impacts are amplified in vulnerable communities whose income and wealth may be less transferable and adaptable than in areas with higher income residents. Equity Priority Communities are census tracts that have a significant concentration of underserved population, such as households with low incomes and people of color. These tracts, along with the 1% AEP flood extents, can be seen on **Figure A-56**.

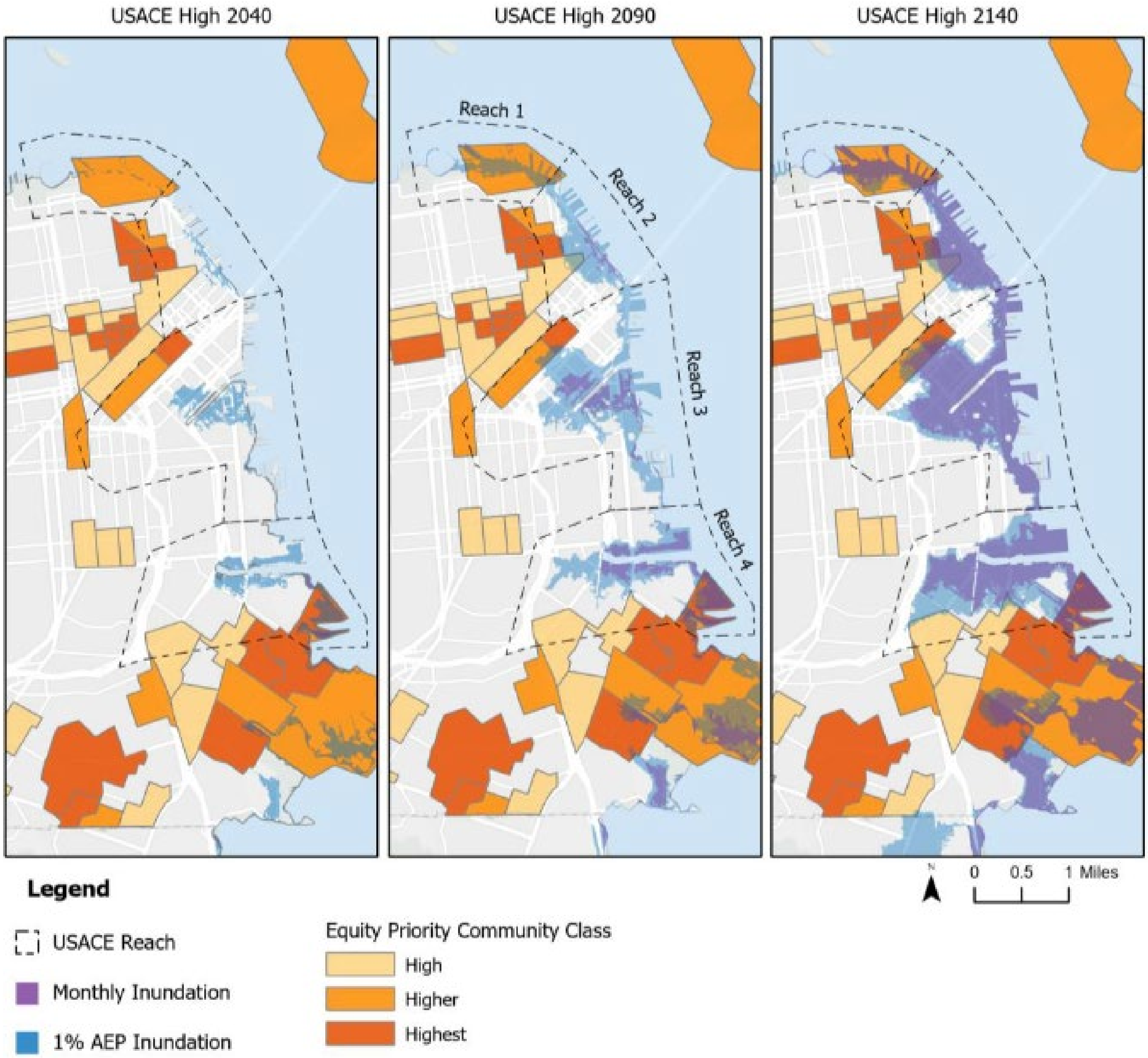


Figure A-56: Equity Priority Communities in the Study Area

Employment is often tied to community and long-term cultivation of opportunities, rather than professional training that can easily be relocated. Access to employment can be transit dependent and impacts to transit can cause proportionally large income losses in vulnerable communities. Lastly, one of the largest factors that contribute to generational wealth is homeownership and the appreciation of the family home over time. Vulnerability to flood hampers appreciation and requires continued repair and investment for those fortunate enough to be homeowners. While BCRs may more easily justify investment in higher value communities, a more nuanced evaluation of the benefits of reducing risk in vulnerable communities can justify longer LODs or additional or higher scaled measures in applicable areas.

***Concerns with Disruptions*:** Constructing structural measures across the San Francisco Waterfront is a large-scale undertaking that will have many key impacts. Disruptions to transit, both public and private, are expected, which will hamper the ability of people to move about the city. These negative impacts have not been quantified, but in highly trafficked areas there is an argument to construct a larger measure to avoid repeated disruption the study area. In a case like Reach 2, this would mean constructing Alternative G (15.5 feet) immediately instead of Alternative D (13.5 feet) with the option to construct Alternative G later. This loss of optionality and earlier cost is traded off with the opportunity to only disrupt the functioning of the city once, consistent with the City's "dig once" principle.

***Compromised Disaster Response Assets*:** In areas where nonstructural actions are recommended, disaster response assets—staging areas, boat launches, mobile hospitals, fire truck connections, and more disaster-related sites—may no longer be accessible during storm events. This may compromise the city's ability to respond to disasters by making it challenging for emergency personnel, supplies, and equipment to reach affected areas. This is one of the types of assets where reducing physical damage through nonstructural means may not be sufficient. Instead, protecting disaster response assets with physical solutions will allow them to function properly and provide value to the waterfront and the city. Considering these assets will support the determination of if an alternative achieves an overall study objective related to post-disaster capacity and resilience.

Historic Districts, including community identity and culturally significant landmarks: Areas along the Northern Waterfront have cultural and historic significance to the community and region and contribute to the regional economy as tourist attractions. Alternatives that preserve or sustain the function and existence of these landmarks contribute net total benefits and may not be correlated with dollar denominated benefits that accrue due to reduced flood damages in the study area.

***Concerns with Water Management Structures*:** As mentioned earlier, Alternative F was screened in Reaches 3 and 4 due to acceptability concerns with the water management structures across Islais and Mission Creeks. Though those alternatives do a good job of reducing flooding in those areas, the acceptability concerns were such that the alternative was not carried forward.

***Maritime Berthing*:** The Maritime Functions key driver comprises exposure to deep draft berthing and backland area, two critical components of an operable maritime port. Several maritime business lines rely on these components of maritime infrastructure to ensure the maritime industry remains viable. The PDT evaluated the FWP impacts on these areas, and like with the Disaster Response Assets, these are impacts that cannot be reduced with nonstructural measures.

A-10.5 Plan Selection

The TNBP was selected as the TSP. The TNBP was developed by varying plan features and alignments by reach to achieve benefits across all four benefit categories and includes risk reduction strategies that do not maximize net NED benefits, but that support adaptability under uncertain timing of RSLC. The TNBP reasonably maximizes net benefits across all four accounts, including EQ and OSE benefit categories. EQ benefits address non-monetary effects on significant natural resources. OSE benefits are social well-being factors that influence personal and group satisfaction, well-being, happiness, public health and safety, equity, vulnerable populations, and disaster response. The TNBP is a better plan than the NED Plan under each RSLC scenario because it facilitates adaptation to achieve cost-effective risk reduction, and supports multiple study area functions over the POA, and is appropriately proposed as the TSP. The reaches where the TNBP selection differs from the NED scale approach for that reach is based upon three broad categories of justifications, listed in priority order:

a) Life Safety: The scales and alignments of measures included in the TNBP to manage flood risk also manage life safety risk from seismic events for users of piers and other structures that are better able to withstand seismic events as a function of the coastal flood risk structural actions.

b) Cost Effectiveness: Given the probability that RSLC will increase flood risk during the 100-year POA, cost effectiveness of the risk reduction strategy was assessed in a two-step evaluation:

    - Net benefits of strategy quantified in terms of flood risk damages avoided over the POA, and professional judgment of the ancillary reduction in multi-hazard risk reduction that is not captured within dollar denominated metrics.
    - Adaptability of measure to align additional height or changed alignment to the initial scale of the plan, to achieve cost-effective risk reduction as RSLC increases over the POA. Adaptation is a necessary component of a cost-effective risk reduction strategy under uncertain timing of RSLC.
    - Construction and subsequent adaptations that would temporarily disrupt communities, transit and economic activities were considered for their overall impacts and influenced the timing and scale of plan selections to be efficient and reduce impacts. This consideration was considered in light of the probability that RSLC will increase flood risk during the 100-year POA.

c) Consistency with USACE objectives to address life safety and regional objectives that emphasize risk reduction in combination with community resilience characteristics, that include:

    - Reducing life safety risk from multiple hazards and supporting emergency and disaster response capabilities.
    - Addressing disparities in the impacts of all hazards.
    - Helping residents and businesses stay and thrive in San Francisco.
    - Restoring and leveraging local ecosystems to help mitigate hazards and support climate adaptation.

The initial action was selected to ensure flood risk is reduced without over-investment, in initial years. Additionally, the total net benefits and adaptive capacity of the initial action were considered in selection. In areas where there was little immediate flood risk, a scaled down version of nonstructural measures would reduce risk to structures and contents. In areas with high potential for multiple, non-monetized benefit streams proactive investment in larger coastal flood risk management alternatives are recommended. The discussion in the previous section suggests potential changes to the strategy that attempts to maximize net NED benefits. The leading reasons for these are:

- RED and OSE benefits correlated with flood risk may support Alternative E in the Southern Waterfront because its alignment is more bayward than Alternative G and, as such, it provides more protection for more assets, land, and people.
- Nonstructural alternatives prevent physical damage but do an incomplete job of preventing RED and OSE losses that may stem from disruption. This may support structural instead of nonstructural first actions in Reaches 1 and 4.
- Vulnerable communities in Reach 4 who live and work around Pier 94-96 and Heron's Head may be impacted by flooding in ways that a nonstructural solution does not mitigate. Disadvantaged communities have less resilience to these impacts; this can be thought of as a "multiplier effect" to the disruption impact discussed above.
- Seismic concerns in all four Reaches may support replacement of wharves, providing life safety benefits and extending the life of some culturally significant landmarks. Replacing wharves also presents the opportunity to preserve maritime berths across the waterfront.
- Resiliency concerns in all four Reaches may support larger construction earlier in the project timeframe, ensuring that measures are resilient throughout the POA. This is the opposite of lining up costs and benefits in time.
- Disaster response assets may not function in areas where nonstructural solutions are chosen. In Reach 4, there are disaster response assets that will face vulnerability in 2040, including assets located by Piers 92 and 94-96 by Islais Creek and Heron's Head Park.
- Major disruptions from construction problems should be avoided if possible. One way to do this is by building adaptable structures or building resilient structures that provide sufficient defense regardless of SLC curve. This is particularly important in Reach 2, where the Embarcadero, a major transportation corridor, will be impacted by construction.

The bullets above imply that there are cost-effective plans that achieve each of these goals and that these plans may differ from the plans that maximize net NED benefits.

"Cost effectiveness" defines that, for each metric, there is a least-cost plan that achieves a desired level of output.

- Structural (Alternative D) in Reaches 1 and 4 instead of nonstructural (Alternative B) as an initial action. This buys down the RED and OSE risks from disruption and provides particular benefit to disadvantaged communities in Reach 4.
- Alternative E as a 2nd Action under the High SLC Curve in Reaches 3 and 4. This reaps the benefits of not retreating from the waterfront, thus protecting businesses, people, maritime function, and disaster response assets.
- Alternative E or G as a 1st Action in Reaches 1 through 4. This provides resiliency to the waterfront against all rates of SLC and provides the most seismic life safety and maritime benefits. This will also mean that a 2nd major construction will be avoided under the High SLC curve because the larger initial actions can be more easily adapted to a higher crest elevation.

Note that neither Alternative C nor Alternative F are mentioned above. For Alternative C, this is because of its lack of adaptability, implying it is not a plan that will provide good outcomes under all rates of RSLC. For Alternative F, it is because of the acceptability concerns discussed earlier.

The PDT decided first that Alternative E would be a better 2nd action than Alternative G in Reaches 3 and 4. This decision was made knowing that the net NED benefits between Alternative E 2nd action and Alternative G 2nd action are reasonably close (Alternative G had \$100 million more in net benefits in Reach 3 and \$400 million in Reach 4). Alternative E protects 292 assets that Alternative G would retreat from (195 in Reach 3 and 97 in Reach 4), but that also means that thousands of people will be saved from impact, millions in RED benefits will be saved (190 of the assets in the area that would be retreated from are commercial or industrial), and in Reach 4, disadvantaged communities won't have their homes and jobs displaced. The differences in OSE and RED benefits between Alternative E and Alternative G are described in more detail in *Appendix E: Economic and Social Considerations*.

Additionally, the PDT intends to refine Alternative E post-draft report. Lessons learned during the design of Alternatives E, F, and G provided more insight into ways to align and construct a cost-effective plan. Leveraging these lessons is expected to lead to a lower-cost plan with minimal changes in benefits with hybridizations on the sub-reach level. This work could make the Alternative E 2nd action have higher net NED benefits than the Alternative G 2nd action. Regardless, because of the clear additional benefits from the Alternative E 2nd action in the Southern Waterfront, it was chosen as the TNBP as an adaptive action in the face of High RSLC.

When considering whether to "go big" with the first action in the name of resiliency, the PDT had to evaluate how feasible doing multiple adaptive actions was. If a first action could be a smaller construction but a larger coastal defense system can be brought online in response to the High rate of SLC, then the costs of the larger construction are not worth incurring up front. When discussing replacing the wharves for maritime and life safety benefits (another benefit of "going big" early), the PDT decided that these benefits were small (in the life safety category) or could be deferred to the later time period (for maritime benefits). As such, incurring the additional cost in 2040 to build a larger plan is not expected to maximize net total benefits.

A major exception to this is in Reach 2. In Reach 2, the seismic life safety risk is considered more severe due to the number of occupants in seismically vulnerable structures in the wharf zone and the Embarcadero's function as a lifeline for the city. The construction disruption is expected to be most impactful in Reach 2 because construction will impact the Embarcadero, likely shutting down lanes of traffic and impacting public transportation and key city-serving utility systems such as the transport/storage boxes for stormwater. Mitigating this risk by building something comprehensive instead of impacting the Embarcadero multiple times with construction is a large benefit to the city. As such, Alternative G is recommended as the 1st action in Reach 2.

The PDT had to decide whether nonstructural or structural was the correct 1st action in Reaches 1 and 4 because nonstructural maximized net NED benefits while structural presented numerous other sources of benefits in the RED and OSE categories. This difficult decision came down to the number of exposed assets at various flood heights, composition of those assets, number of people exposed, and existing resiliency of the communities. With these factors in mind, it was decided that Alternative B would remain the first action for Reach 1 while Alternative D would maximize net total benefits in Reach 4.

The TNBP first and second actions are shown in **Table A-45**.

Table A-45: TNBP First and Second Actions

Reach	First Action All RSLCs	Second Action Low RSLC	Second Action Intermediate RSLC	Second Action High RSLC
1	Alternative B	N/A	Alternative B (Additional NS)	Alternative G 19'
2	Alternative G 15.5'	N/A	N/A	Alternative G 19'
3	Alternative D 13.5'	N/A	Alternative D 15.5'	Alternative E 19'
4	Alternative D 13.5'	N/A	Alternative D 15.5'	Alternative E 19'

Section A-11. Tentatively Selected Plan

The TNBP with seismic ground improvements is identified as the TSP because it is responsive to the study guidance and creates a resiliency strategy that maximizes effectiveness across a broad array of future risk scenarios.

The TSP as described here follows the planning assumptions required for analysis, using 2040 and 2090 as approximate first and subsequent action years. However, the PDT recognizes that the TSP subsequent actions will be reconsidered over time based on monitoring SLR and other changing conditions, as described in *Appendix G: Monitoring and Adaptation Plan*. **Figure A-57** illustrates the conceptual framework for the range of TSP subsequent actions. As shown in **Figure A-57**, the TSP first actions are independent of the RSLC curve. However, due to the uncertainty of RSLC, the PDT assumed the Intermediate-High RSLC second actions in describing the TSP and for analysis in the NEPA process. This is in line with the extrapolation of observed SLR in this region, which is trending above the USACE Intermediate curve and below the USACE High curve, as described in *Appendix J: Climate*. The Intermediate-High RSLC second actions described in the TSP for the NEPA process were selected to reflect impacts beyond those associated with the Intermediate RSLC second actions without overstating the potential benefits.

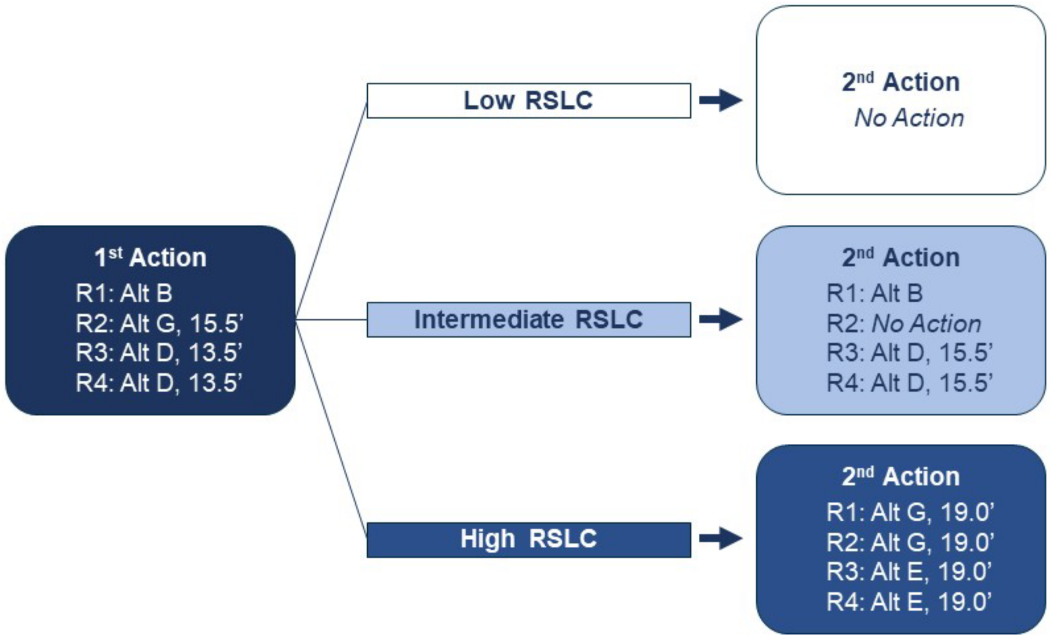


Figure A-57: Conceptual Framework for TSP First Actions and Potential Range of TSP Subsequent Actions

The TSP includes NNBFs for coastal flood risk reduction, and it can be further optimized for NNBFs by reviewing the full range of NNBFs across all alternatives, selecting the best NNBFs to maximize coastal flood risk reduction and net benefits (*Appendix I: Engineering with Nature*), and incorporating them as part of future plan refinements.

The TSP is a cost effective, hybridized plan that combines retreat and defend measures, scaled to perform under the lowest initial risk and to adapt to risk of a higher rate of RSLC as a potential subsequent action. Initial actions (**Figure A-58**) are proposed to align expenditures and subsequent actions (**Figure A-59**) that add height or adapt measures with the arrival of increased risk in later years..

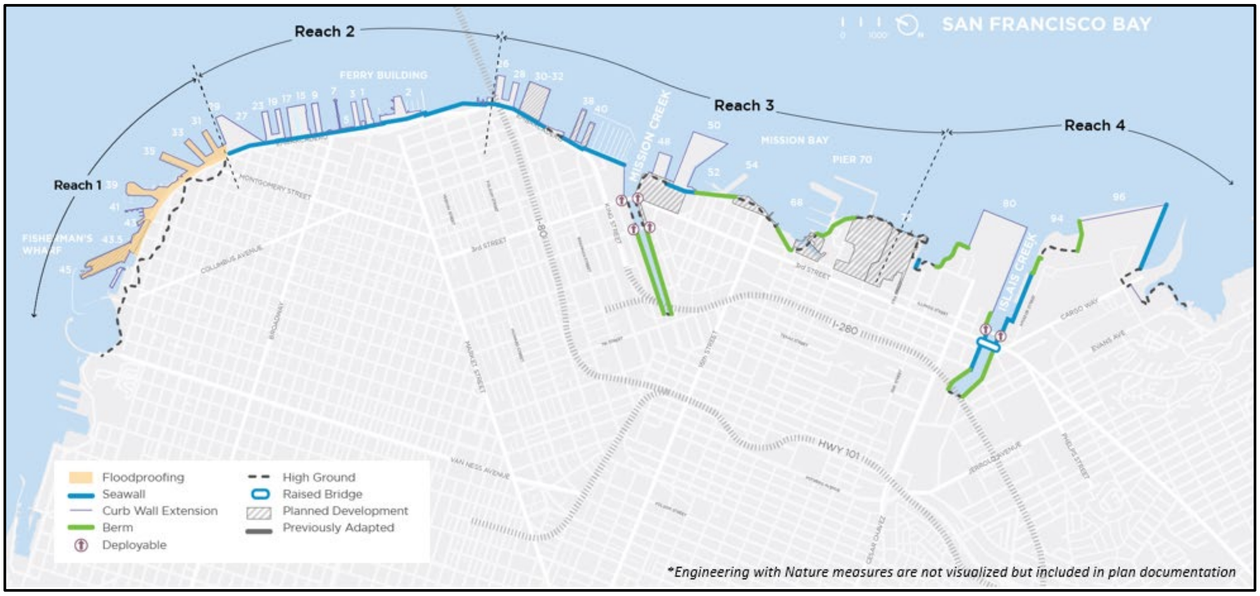


Figure A-58: Proposed First Actions for the TSP

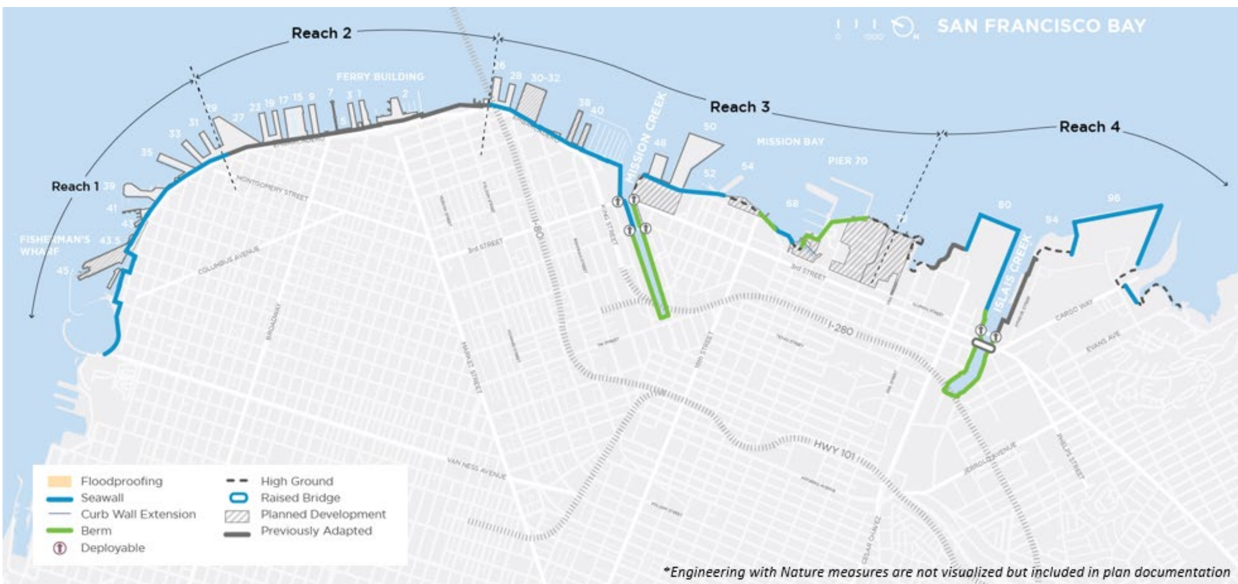


Figure A-59: Proposed Second Actions for the TSP

The features of the TSP by reach for initial actions and subsequent actions are described below.

A-11.1 Embarcadero (Reaches 1 and 2)

In Fisherman's Wharf, the TSP initially relies on floodproofing buildings, and later elevates the shoreline with floodwalls. Along the Embarcadero, the TSP elevates the shoreline in place by raising and reconstructing the bulkhead walls and pile-supported wharves north of the Bay Bridge while gradually transitioning down from the new shoreline elevation back to the existing city grade to retain visual and physical access to the waterfront. The plan includes reconstruction and redesign of the Embarcadero roadway – surface design of the Embarcadero roadway and promenade will be determined in future project phases. The Ferry Building and bulkhead buildings are raised in place. Piers are floodproofed with concrete curbs around the perimeter to reduce flood risk.

The TSP in Reaches 1 and 2 includes the following **initial actions** (**Figure A-60** to **Gray and** black represent existing conditions; orange and purple represent TSP first actions.

Figure A-63):

- From Pier 27-29 to the Bay Bridge, raise the shoreline along the Embarcadero by 3.5 to 7.5 feet to defend against 3.5 feet of SLR (finish elevation of 15.5 feet NAVD88) using raised and rebuilt bulkhead walls and wharves, approximately aligned with the location of the existing structures. Provide Embarcadero Promenade and Bay Trail access atop and adjacent to the raised ground and wharves.
- Perform ground improvement to reduce lateral spreading and liquefaction risk along the coastal flood defense alignment to ensure desired seismic performance.
- Construct 2-foot-tall concrete curb around perimeter of piers from Pier 47 to Pier 24.
- Replace existing wharves with new ductile concrete wharves with deck elevation to match top of new bulkhead seawall. Transition grade from raised wharf and bulkhead building to existing pier elevation.
- Raising the shoreline in place requires reconstruction of the full Embarcadero roadway and results in a likely reduction of overall roadway width. Design of the mobility corridor and specific utilization of the available space will be done during the PED phase.
- Elevate buildings on wharves north of the Bay Bridge, including the Ferry Building, Agriculture Building, bulkhead buildings, and more.
- Floodproof a subset of buildings in Fisherman’s Wharf, such as the Dolphin Club and buildings at Pier 45, Pier 39, and Pier 31.
- Consider removing or floodproofing select additional buildings in Fisherman's Wharf based on risk profile, age, condition, and historic status.
- Build infrastructure to manage stormwater. Coordinate with SFPUC, San Francisco Public Works, and other stakeholders on changes to the combined sewer system, expanded green corridors and other features to reduce inland flood risk exacerbated by the coastal flood defense structures.

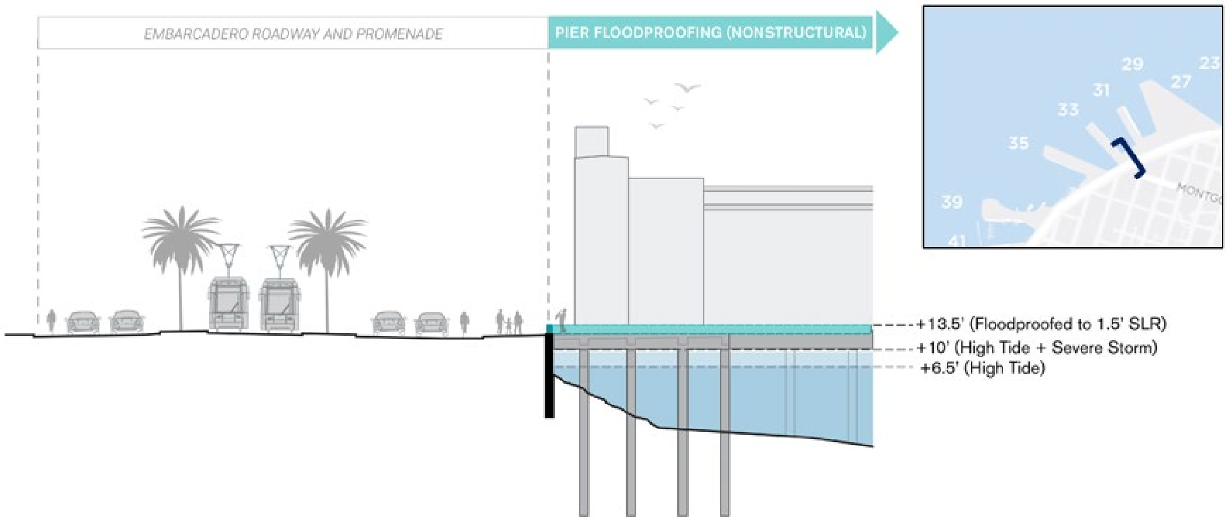
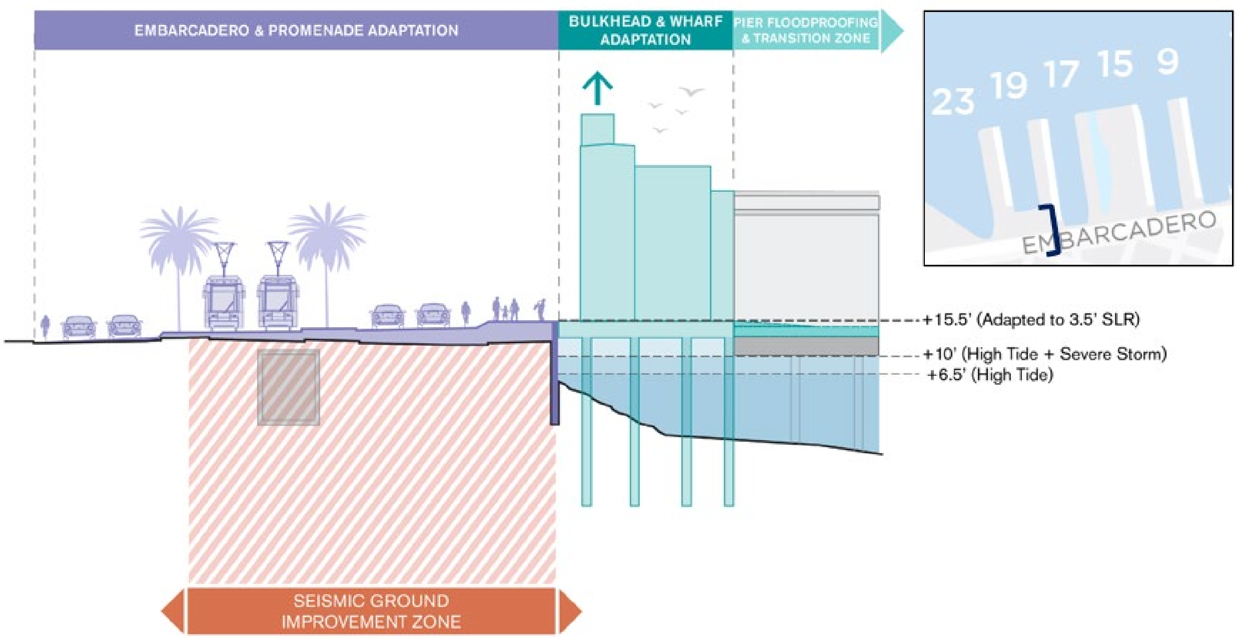


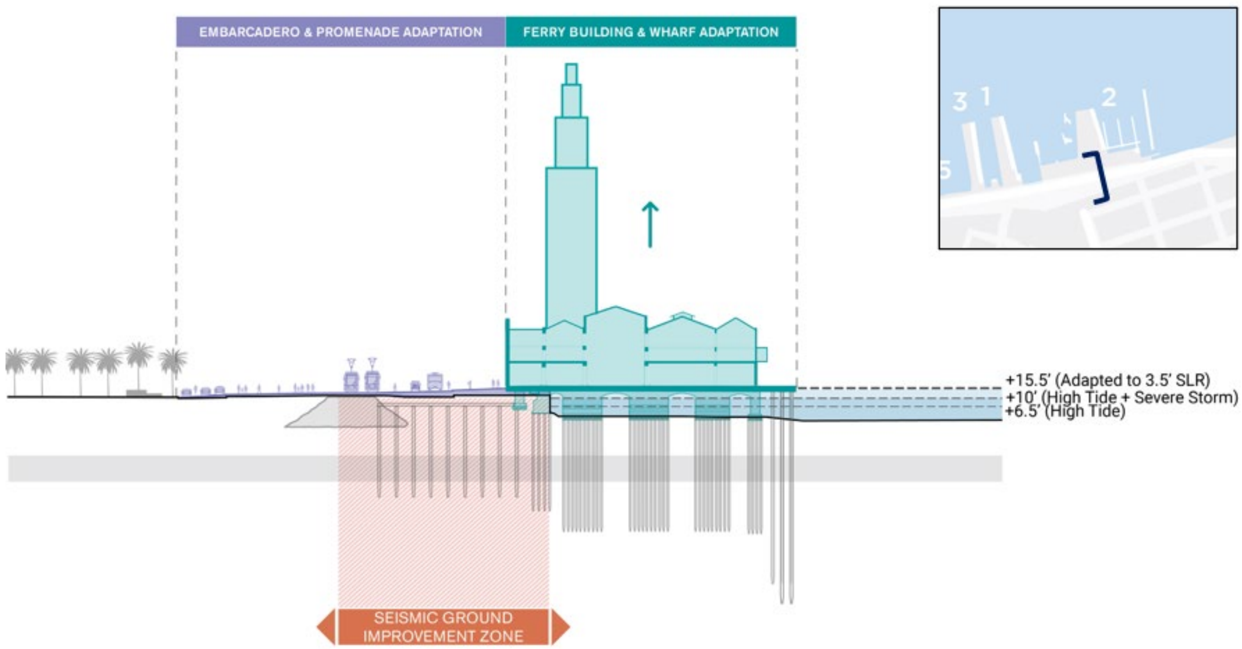
Figure A-60: TSP First Actions: Fisherman's Wharf to Telegraph Hill (Reach 1), Typical Cross Section within Embarcadero Historic District

Gray and black represent existing conditions; teal represents TSP first actions.



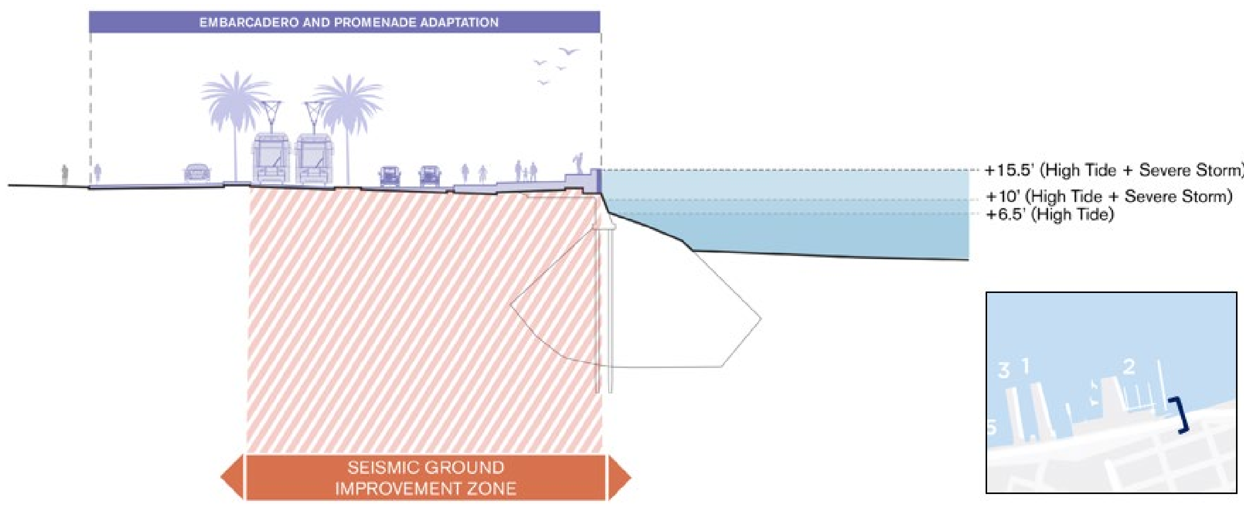
Gray and black represent existing conditions; orange, purple, and teal represent TSP first actions.

Figure A-61: TSP First Actions: Telegraph Hill to Bay Bridge (Reach 2), Typical Cross Section within Embarcadero Historic District



Gray and black represent existing conditions; orange, purple, and teal represent TSP first actions.

Figure A-62: TSP First Actions: Telegraph Hill to Bay Bridge (Reach 2), Ferry Building



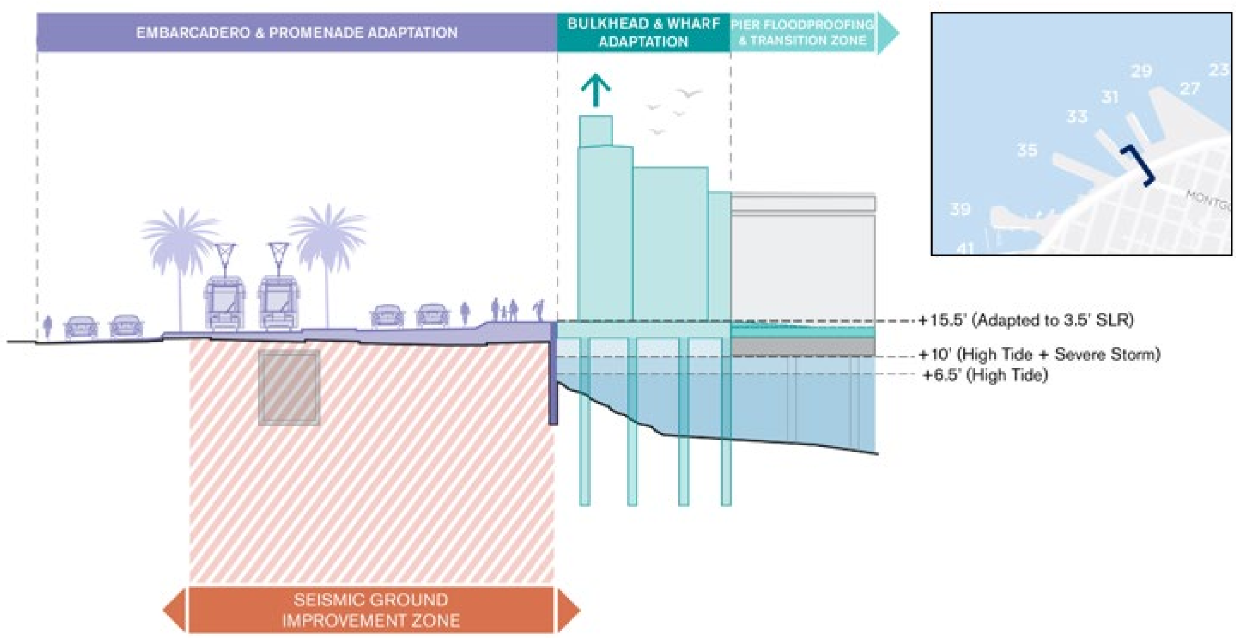
Gray and black represent existing conditions; orange and purple represent TSP first actions.

Figure A-63: TSP First Actions: Telegraph Hill to Bay Bridge (Reach 2), Rincon Park

The TSP in Reaches 1 and 2 includes the following **subsequent actions** (**Figure** A-64):

- North of Pier 27-29, raise the shoreline by 1.5 to 4.5 feet to defend against 3.5 feet of SLR (15.5 feet NAVD88) using 1.5- to 4.5-foot-tall floodwalls and raised and rebuilt bulkhead walls and wharves, approximately aligned with the location of these existing structures. Provide Embarcadero Promenade and Bay Trail access along or adjacent to the flood defense structure.

- Perform ground improvement to reduce lateral spreading and liquefaction risk along the coastal flood defense alignment to ensure desired seismic performance.
- Consider elevation, floodproofing, or demolition of buildings bayside of the coastal flood defense in Fisherman's Wharf based on risk profile, age, condition, and historic status.
- Build infrastructure to manage stormwater. Coordinate with SFPUC, San Francisco Public Works, and other stakeholders on changes to the combined sewer system, new pumps, green infrastructure, other resilient building and street design opportunities, and other features to reduce inland flood risk exacerbated by the coastal flood defense structures.
- As sea levels rise, additional adaptations may be needed before the end of the POA (2140), but these are not anticipated to be included in the project to be authorized for funding at this time. For the purposes of analysis, these are assumed to further raise the coastal flood defense using primarily vertical extension walls.



Gray and black represent post-first-action conditions; orange, purple, and teal represent TSP subsequent actions. Further design studies will be needed to incorporate bicycle infrastructure planning efforts, vehicular access considerations, and urban design considerations.

Figure A-64: TSP Subsequent Actions: Fisherman's Wharf to Telegraph Hill (Reach 1), Typical Cross Section within Embarcadero Historic District

A-11.2 Mission Creek/Mission Bay (Reach 3)

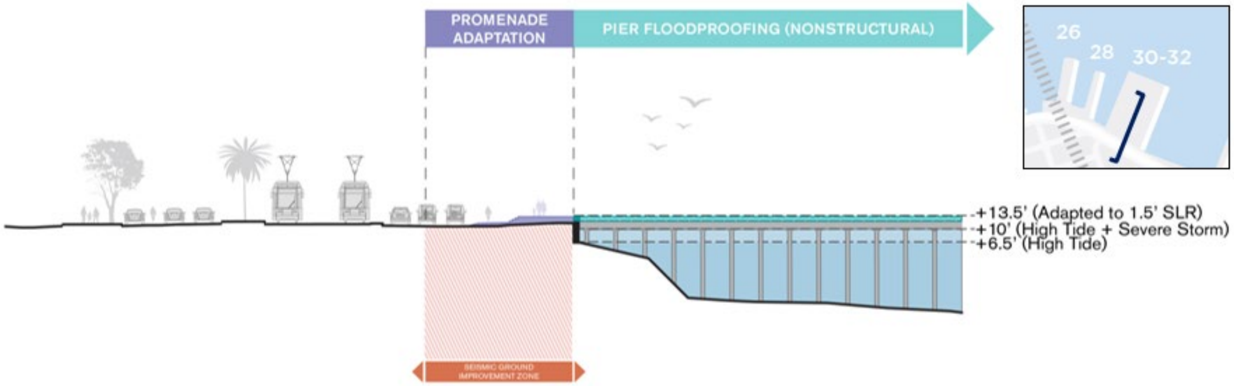
In the Mission Creek/Mission Bay geography, the TSP defends existing city and community assets in place by elevating the creek and Bay shorelines with levees, floodwalls, and raised and rebuilt bulkhead walls and wharves. The coastal defense will tie into existing and planned high ground at Bayfront, Agua Vista and Crane Cove Parks, and the Mission Rock and Pier 70 development areas. The plan also includes partial reconstruction and redesign of the Embarcadero roadway south of the Bay Bridge.

The TSP in Reach 3 includes the following **initial actions** (**Figure A-65** to **Figure** A-67):

- Raise the Bay and creek shorelines to defend against 1.5 feet of SLR (13.5 feet NAVD88) using a combination of 1.5- to 4.5-foot-tall walls, levees, and raised and rebuilt bulkhead walls and wharves, depending on existing shoreline elevations. Provide Bay Trail access atop and adjacent to bayside levees and wharves.
- Install 2-foot-tall concrete curbs around the perimeters of piers from Pier 26 to Pier 50.
- Perform ground improvement to reduce lateral spreading and liquefaction risk along the coastal flood defense alignment to ensure desired seismic performance.
- Install deployable closure structures at the northern and southern abutments of 3rd and 4th Street bridges over the creek to defend landward buildings and infrastructure from flood damage. Service across bridges will be disrupted for hours to days during high water events. The likelihood of closure is anticipated to be approximately one closure on average every 25-200 years (0.5-4% annual chance) by 2060.[7]
- Tie measures into existing high ground and planned development projects at Bayfront, Agua Vista and Crane Cove Parks, and the Mission Rock and Pier 70 development areas.
- Enhance wildlife habitat on levees along the shoreline using NNBFs.
- Remove select buildings at Pier 68/70 shipyard for construction of coastal levee or adjust the alignment of coastal levee features to avoid historic resources where the structures have ground floor elevations that are above 13.5 feet NAVD88.
- Build infrastructure to manage stormwater. Coordinate with SFPUC, San Francisco Public Works, and other stakeholders on changes to the combined

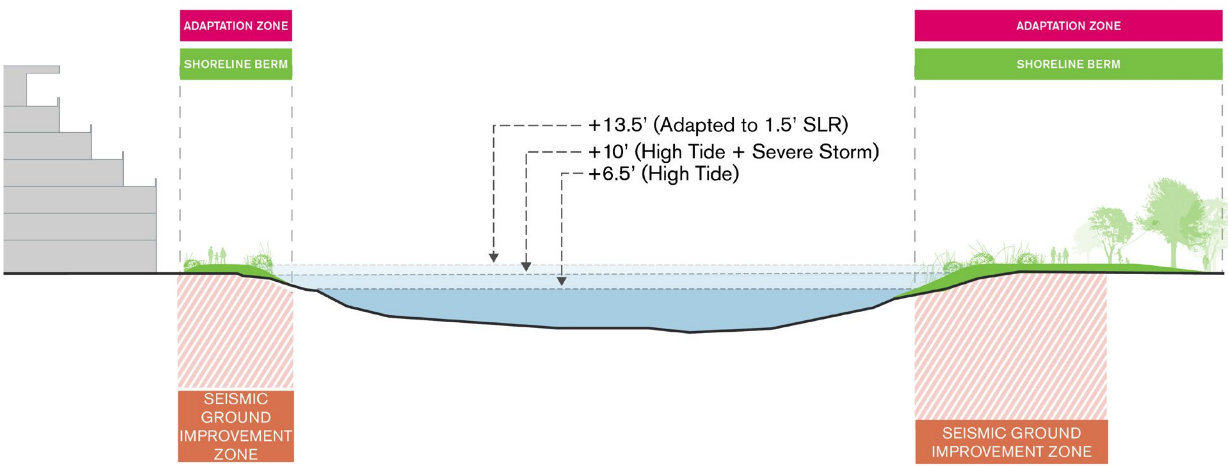
[7] Based on USACE intermediate and high RSLC.

sewer system, expanded green corridors, and other features to reduce inland flood risk exacerbated by the coastal flood defense structures.



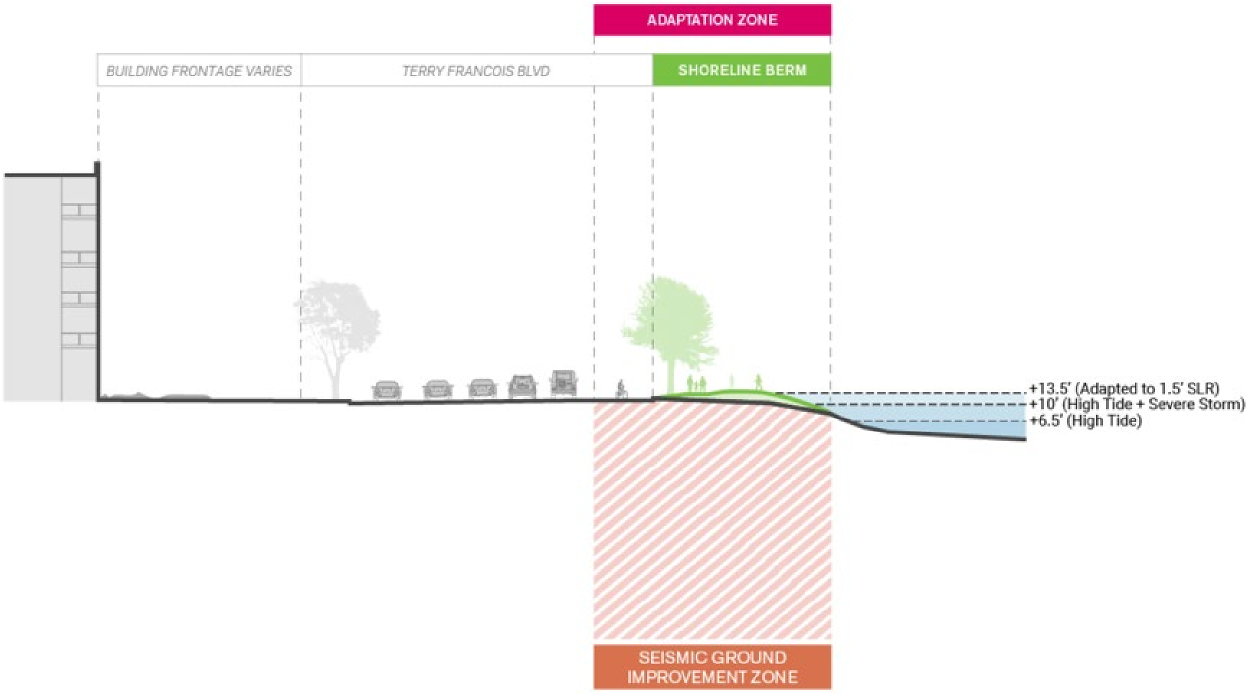
Gray and black represent existing conditions; orange, purple, and teal represent TSP first actions.

Figure A-65: TSP First Actions: Bay Bridge to Potrero Point (Reach 3), Pier 30/32



Gray and black represent existing conditions; orange, pink, and green represent TSP first actions.

Figure A-66: TSP First Actions: Bay Bridge to Potrero Point (Reach 3), Mission Creek



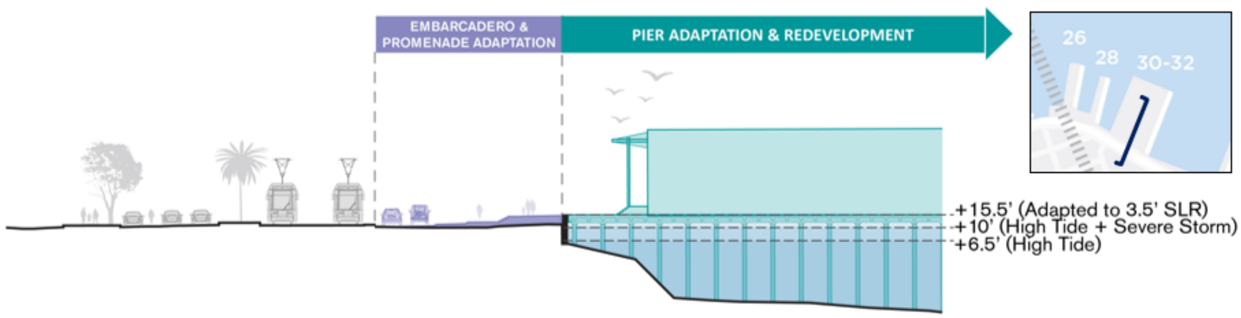
Gray and black represent existing conditions; orange, pink, and green represent TSP first actions.

Figure A-67: TSP First Actions: Bay Bridge to Potrero Point (Reach 3), Terry Francois Boulevard

The TSP in Reach 3 includes the following **subsequent actions** (**Figure A-68** to **Figure A-70**):

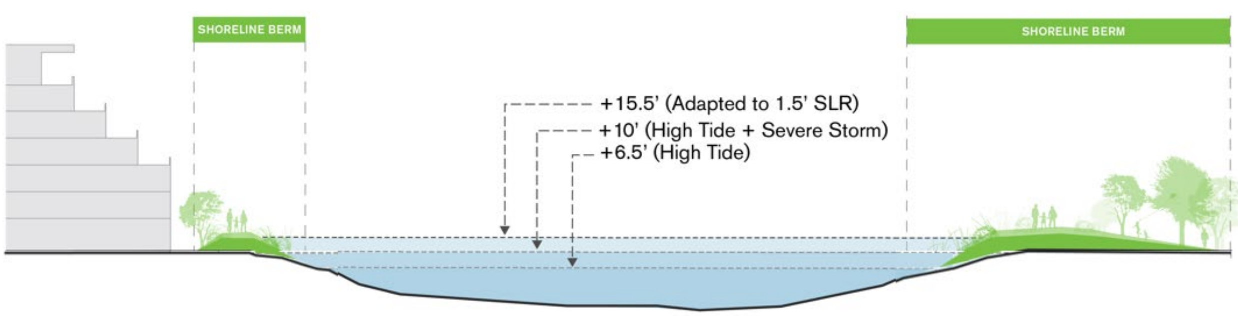
- Raise the Bay and creek shorelines an additional 2 feet to defend against 3.5 feet of SLR (15.5 feet NAVD88) using levees and seawalls, as well as raising and rebuilding bulkhead walls and wharves. Provide Bay Trail access atop and adjacent to the levees and wharves.
- Perform additional ground improvement to reduce lateral spreading and liquefaction risk along the coastal flood defense alignment where required to ensure desired seismic performance.
- Maintain current roadway capacity along Terry Francois Boulevard and reduce one lane of parking to provide space for shoreline elevation and regrading. Final surface design will be conducted in future design phases.
- Consider modest amount of new Bay fill along the Bay edge at Terry Francois Boulevard and north bank of Mission Creek from the 4th Street Bridge to South Beach Harbor.
- Incorporate NNBFs along the creek and Bay shorelines to serve a coastal flood risk management function by reducing wave runup, while also enhancing public access and wildlife habitat.

- Elevate bulkhead buildings from Pier 26 through Pier 50. Consider elevation, floodproofing, or demolition of other buildings along the bayside shoreline overlapping or adjacent to the coastal flood defense alignment based on risk profile, age, condition, and historic status.
- Consider building additional infrastructure to manage stormwater and reduce inland flood risk exacerbated by the coastal flood defense structures.
- As sea levels rise, additional adaptations may be needed before the end of the POA (2140), but these are not anticipated to be included in the project to be authorized for funding at this time. For the purposes of analysis, these are assumed to further raise the coastal flood defense using primarily vertical extension walls.



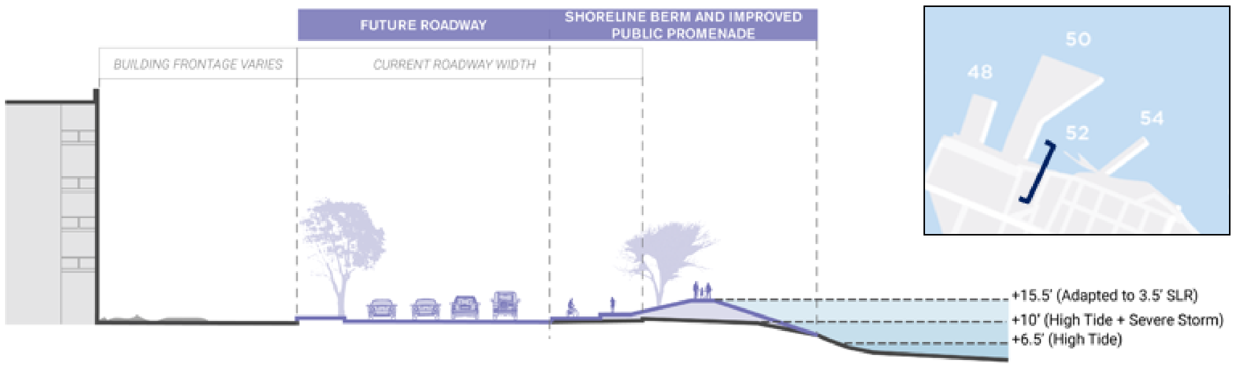
Gray and black represent post-first-action conditions; purple and teal represent TSP subsequent actions and example potential actions in coordination with development partners.

Figure A-68: TSP Subsequent Actions: Bay Bridge to Potrero Point (Reach 3), Pier 30/32



Gray and black represent post-first-action conditions; green represents TSP subsequent actions.

Figure A-69: TSP Subsequent Actions: Bay Bridge to Potrero Point (Reach 3), Mission Creek



Gray and black represent post-first-action conditions; purple represents TSP subsequent actions.

Figure A-70: TSP Subsequent Actions: Bay Bridge to Potrero Point (Reach 3), Terry Francois Boulevard

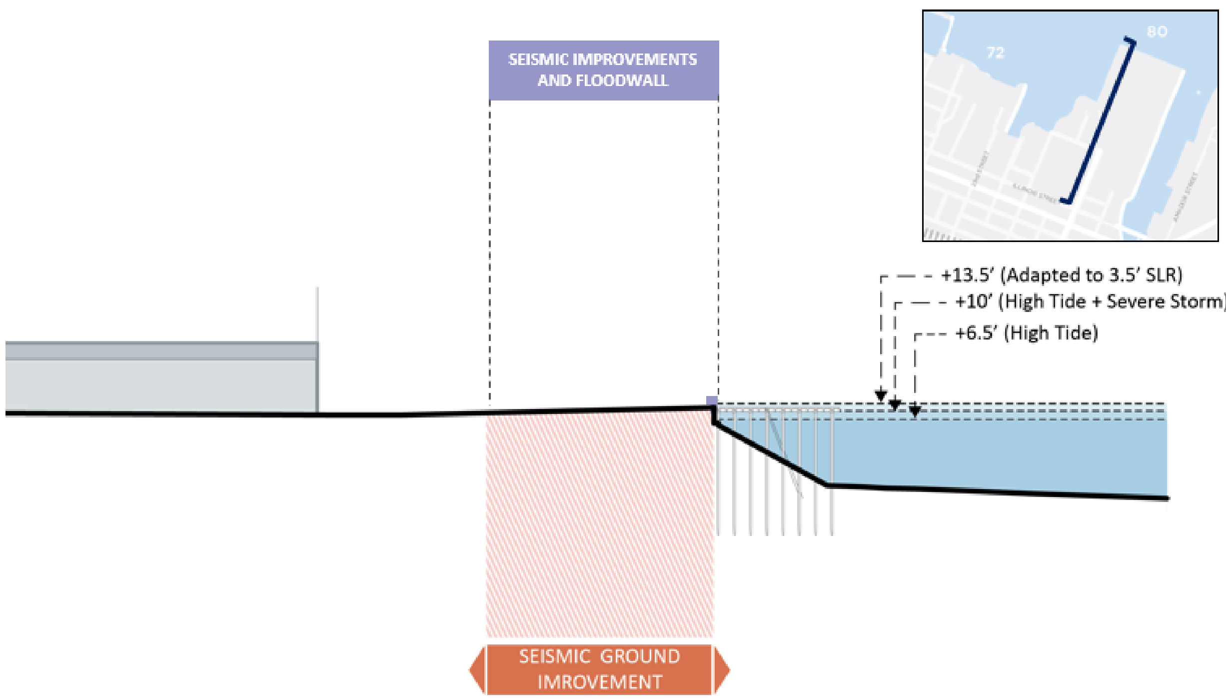
A-11.3 Islais Creek/Bayview (Reach 4)

In the Islais Creek/Bayview geography, the TSP defends the existing shoreline to retain residential and commercial land uses in place, including POSF land uses and maritime facilities. The flood defenses consist of raising the shoreline using levees and bulkhead walls, raising and rebuilding marginal wharves and deployable closure structures, and tying into existing or planned high ground near Potrero Power Station and behind the Pier 94 Wetlands (Port backlands). This area of the waterfront contains large parcels independent of the combined sewer system, such that the elevated shoreline will require modification to handle stormwater in a safe and effective manner.

The TSP in Reach 4 includes the following **initial actions** (**Figure A-71** to **Figure** A-73):

- Elevate the Bay and creek shorelines using a combination of 2.5- to 5.5-foot-tall levees, floodwalls, and curb extensions to defend against 1.5 feet of SLR (13.5 feet NAVD88). Defenses tie into high ground at Warm Water Cove, the western end of Islais Creek, Pier 94 Wetlands, Heron's Head Park, and near the southern boundary of the study area.
- Install 2-foot-tall concrete curb at edge of Pier 80 and Pier 94-96 to provide coastal flood protection while maintaining function for maritime uses.
- Perform ground improvement to reduce lateral spreading and liquefaction risk along the coastal flood defense alignment to ensure desired seismic performance.
- Incorporate NNBFs into Warm Water Cove, at the interface of Pier 94 Wetlands and Pier 96, and along portions of the Islais Creek bank.
- Install deployable closure structures at the north and south abutments of Illinois Street Bridge to be activated in advance of a coastal storm.

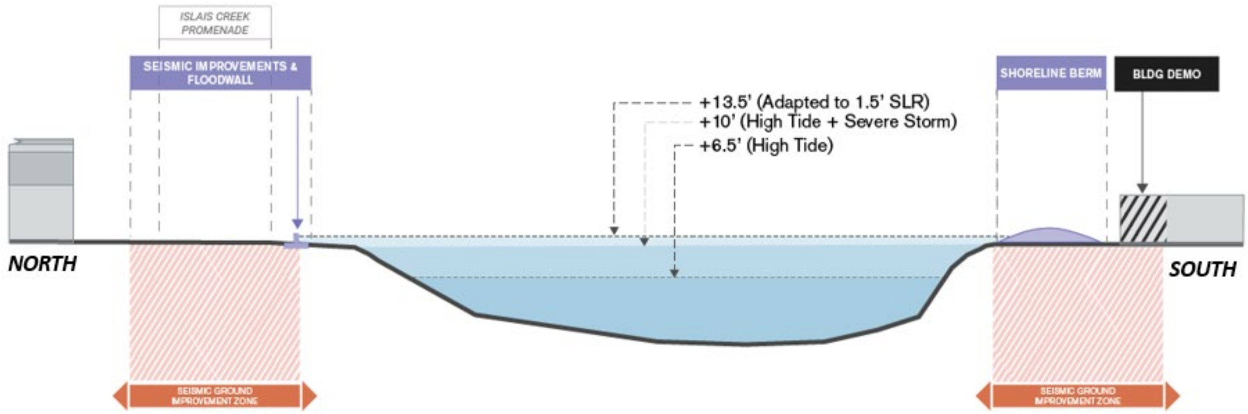
- 3rd Street Bridge will be rebuilt at a higher elevation[8] per the San Francisco Public Works existing project, outside of the Flood Study (FWOP condition).
- Reconstruct Pier 90 and 92 wharves at 13.5 feet NAVD88 elevation and incorporate them into the coastal defense system.
- Consider removing portions of warehouses near the south banks of Islais Creek and west of the bridges to make room for levee features, as well as portions of the Pier 96 building that extends south of the pier edge, and one building straddling the wharf edge at Pier 90.
- Build infrastructure to manage stormwater. Coordinate with SFPUC, San Francisco Public Works, and other stakeholders on changes to the combined sewer system, expanded green corridors, and other features to reduce inland flood risk exacerbated by the coastal flood defense structures.



Gray and black represent existing conditions; orange and purple represent TSP first actions.

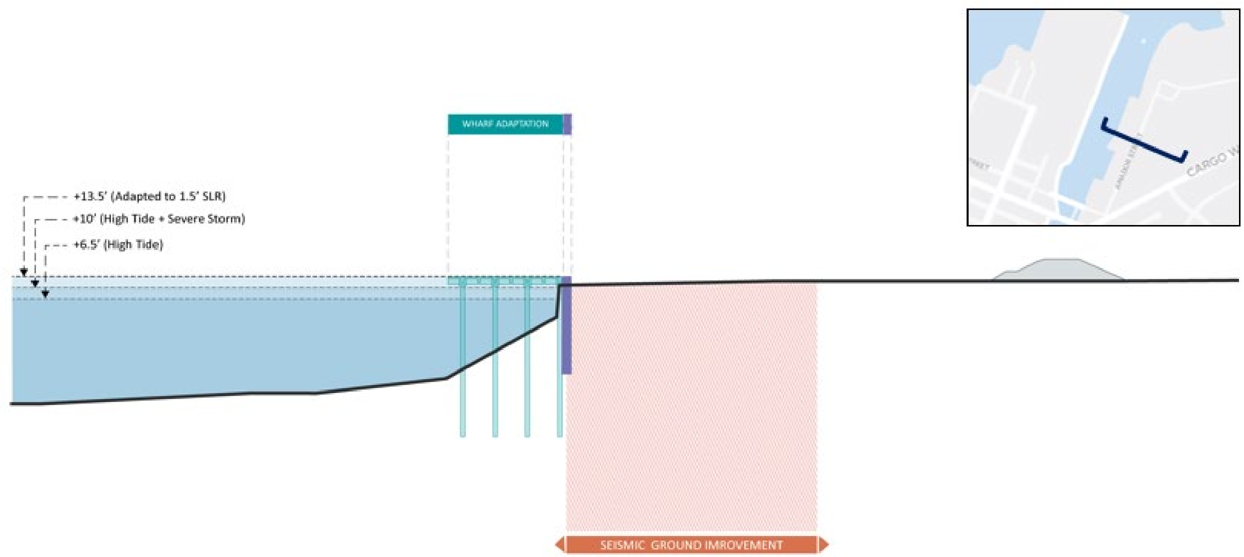
Figure A-71: TSP First Actions: Potrero Point to Heron's Head Park (Reach 4), Pier 80

[8] Rebuilding of 3rd Street Bridge at higher elevation is external to the Flood Study project (i.e., it is part of the FWOP condition).



Gray and black represent existing conditions; orange and purple represent TSP first actions.

Figure A-72: TSP First Actions: Potrero Point to Heron's Head Park (Reach 4), Islais Creek



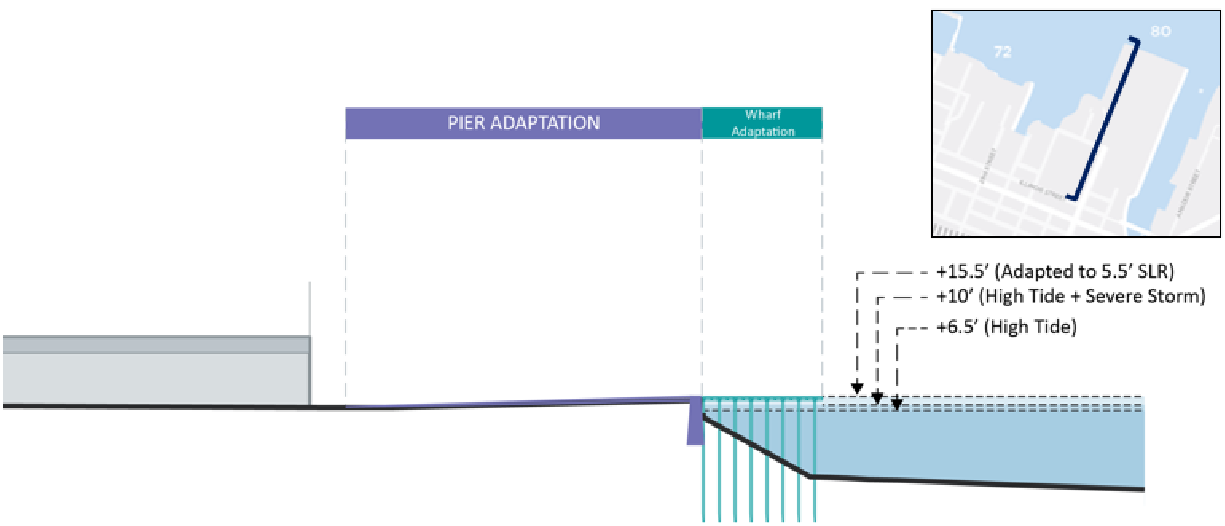
Gray and black represent existing conditions; orange, purple and teal represent TSP first actions.

Figure A-73: TSP First Actions: Potrero Point to Heron's Head Park (Reach 4), Pier 92

The TSP in Reach 4 includes the following **<u>subsequent actions</u>** (**Figure A-74** and **Figure A-75**):

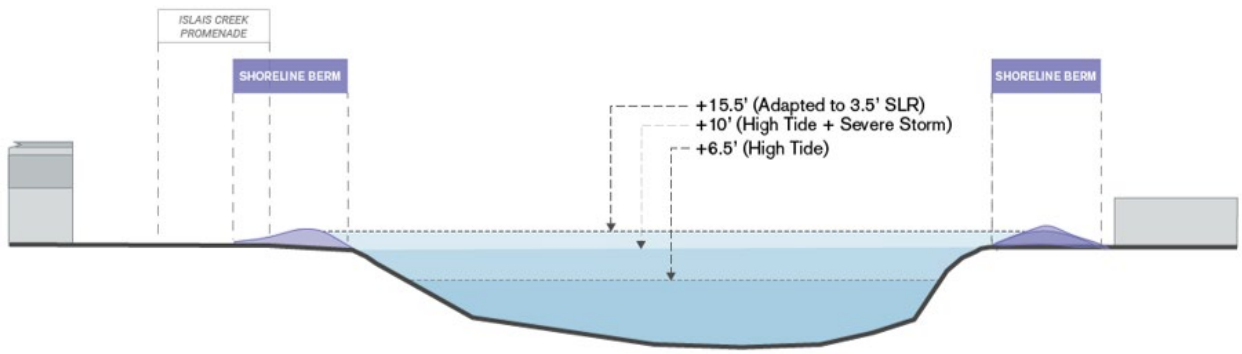
- Elevate the Bay and creek shorelines an additional 2 feet using a combination of levees, floodwalls, and raised bulkhead walls and wharves to defend against 3.5 feet of SLR (15.5 feet NAVD88).
- Perform additional ground improvement to reduce lateral spreading and liquefaction risk along the coastal flood defense where required to ensure desired seismic performance.

- Construct levees along the banks of Islais Creek west of the Illinois Street Bridge and from Illinois Street Bridge to Pier 80.
- Incorporate NNBFs into the shoreline along the banks of Islais Creek and Pier 94 wetlands to serve a coastal flood risk management function by breaking and attenuating waves, while also enhancing public access and wildlife habitat.
- Adapt Pier 80 and Piers 94-96 by installing a new raised bulkhead wall and wharves.
- Consider removing buildings that straddle the alignment of the new bulkhead wall based on risk profile, age, condition, and historic status.
- Consider building additional infrastructure to manage stormwater and reduce inland flood risk exacerbated by the coastal flood defense structures.
- As sea levels rise, additional adaptations may be needed before the end of the POA (2140), but these are not anticipated to be included in the project to be authorized for funding at this time. For the purposes of analysis, these are assumed to further raise the coastal flood defense using primarily vertical extension walls.



Gray and black represent post-first-action conditions; orange and purple represent TSP subsequent actions.

Figure A-74: TSP Subsequent Actions: Potrero Point to Heron’s Head Park (Reach 4), Pier 80



Gray and black represent post-first-action conditions; orange and purple represent TSP subsequent actions.

Figure A-75: TSP Subsequent Actions: Potrero Point to Heron's Head Park (Reach 4), Islais Creek

A-11.4 Regret and Adaptation Analysis

The TSP was informed by a preliminary assessment of the regret of over-investment and under-investment and responds to different RSLC scenarios. It does not address multi-hazard scenarios as part of its first adaptation actions or include subreach level refinements. The PDT will consider these issues as part of continuing plan refinement for the final report.

There are many uncertainties that need to be considered if the final recommended plan is to be an economically efficient, risk-informed plan that addresses multiple hazards. These uncertainties include:

- High level of uncertainty in the rates of RSLC along the San Francisco shoreline and resulting coastal flood damages
- High risk of life loss and injury in the event of an earthquake
- Residual life of historic assets along the waterfront that are implicated by the plan that will require replacement in the next 40 years
- Uncertainty associated with Federal and local funding given preliminary plan cost estimates
- Uncertainty associated with project risks such as litigation

These uncertainties suggest the need to build in a margin of safety when planning for implementation of a final recommended plan relative to when analysis suggests intervention is required to address flood risk. See **Figure A-77** below.

The PDT will consider these uncertainties, conduct further Regret and Adaptation Analysis, and review public, agency, and technical reviewer comments on the draft report to make changes to the TSP and to develop a more refined MAP.

In developing the TSP, the PDT used 2040 and 2090 as planning-level proxies for 1st and 2nd adaptation actions. Using the FWOP and FWP risk and total benefits analysis, the PDT arrived at the TSP with a series of initial actions to address 1.5 feet of SLC, with a range of second actions to address 3.5 feet of SLC. Both the initial and second actions were drawn from the existing alternatives.

To address the uncertainties detailed above within the final plan, the PDT proposes to continue applying a Regrets and Adaptation Analysis. An initial regrets analysis was undertaken in developing the TSP and will be refined as the study advances to support decision-making about the cost and scale of first and subsequent adaptation actions.

The analysis completed to date considered the regret of over- or under-investment in response to different RSLC scenarios based on the Low, Intermediate, and High USACE RSLC scenarios (**Figure A-76**), and the high current seismic risk.

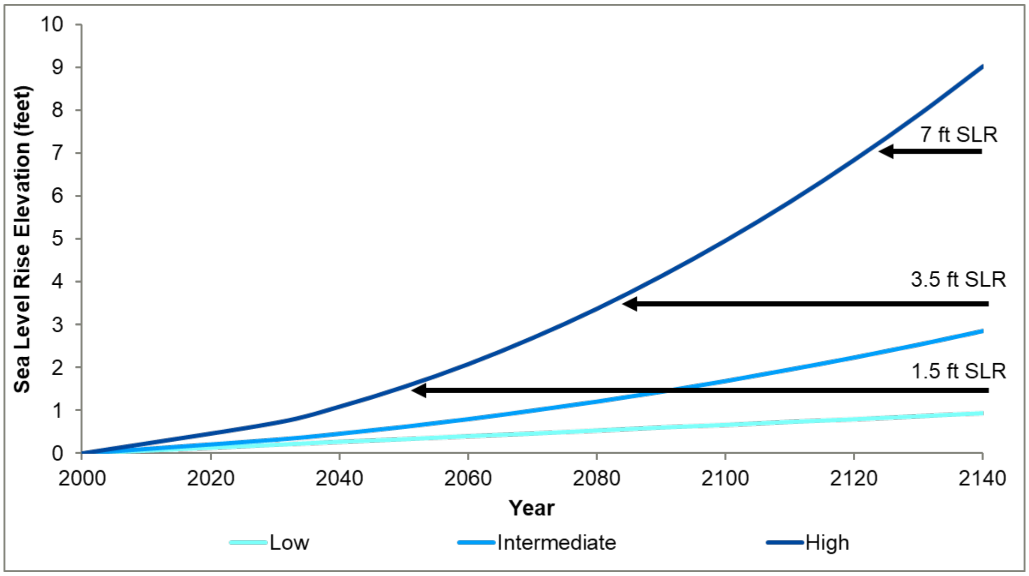


Figure A-76: USACE RSLC Projections

Examples of regret of over-investment that were considered include:

- Negative net benefits associated with construction of plan features too far in advance of the design water level
- Introducing future coastal life safety risk by raising the existing shoreline where retreat from the future floodplain is a viable option
- Inability for the current generation to pay (e.g., insufficient funding in the USACE annual budget or insufficient local capital funding for the coastal flood risk management project local match and/or required HTRW cleanup activities)

Examples of under-investment that were considered include:

- Substantial monetary and non-monetary damages due to coastal flooding overtopping the shoreline (high residual risk)
- Failure to address seismic life safety risk in vulnerable structures along the shoreline
- Loss of historic resources before planned wharf replacements

- Non-adaptive initial investment
- Inability for a future generation to pay

In the plan refinement phase of the study, the PDT will further develop the regrets analysis and undertake an adaptation analysis. The PDT intends to use this Regrets and Adaptation Analysis to shape a final recommendation regarding federal and local investment in a coastal flood risk management system by:

- Examining first and possible second adaptation actions and the scaling (sizing) of these actions
- Considering both monitoring and anticipatory (precautionary) actions given the uncertainties
- Developing defined triggers to begin design or construction of subsequent adaptation actions

This additional analysis will allow the PDT to develop a phasing plan with adaptation pathways and defined triggers for subsequent action that can be considered as part of the final recommended plan.

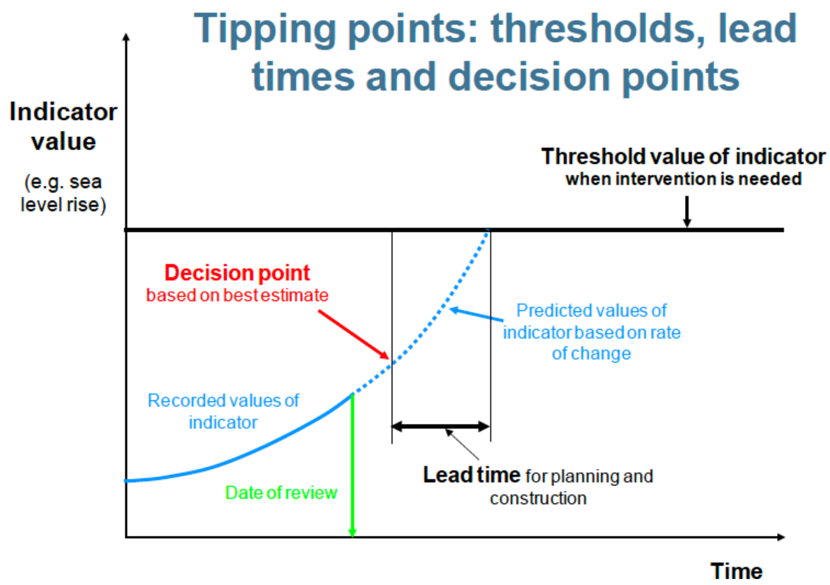
The adaptation analysis will include an examination of the timing of second adaptation actions, the lead time to design and construct those actions, and when design or construction work needs to start given the projected performance of first adaptation actions under the Low, Intermediate, and High USACE RSLC scenarios.

The current state of RSLC science has a level of uncertainty that does not allow the PDT to recommend one RSLC scenario to inform scaling of actions, which is consistent with study guidance. According to the latest Federal interagency analysis, the current SLC trend in this region is slightly above the Southwest intermediate RSLC curve (Sweet 2022), which is higher than the USACE Intermediate curve. Certainty on the rates of RSLC will improve over time and the PDT expects the Federal government and the State of California will publish new guidance related to RSLC projections with increasing levels of confidence to support decision-making, reinforcing the need for a flexible decision-making framework.

Based on current science, the Low, Intermediate, and High RSLC scenarios do not produce significant differences until between 2040 and 2050 (**Figure A-76**). With improving science and understanding of emissions in the coming decades, it is reasonable to assume that between 2040 and 2050, USACE and POSF will have greater certainty about the actual RSLC trajectory.

When assessing the trigger points to plan for the second and/or subsequent actions, it is important to understand and consider the timescales for planning, design, construction, and acquisition of funding to estimate a “lead time.” **Figure A-77** depicts how to consider lead time in an adaptation plan. The PDT estimated an initial lead time that suggested if the RSLC tracks the projected high rate of rise, USACE would need to request, and Congress would need to authorize and appropriate funding, for the design of the subsequent adaptation action(s) before the construction of the first adaptation actions are completed. Furthermore, the recommendation would need to be authorized and funding appropriated before any RSLC monitoring program may signal that the rate of rise is tracking on the high USACE RSLC curve.

This finding suggests considering a range of precautionary (anticipatory) actions in the final recommended plan. This finding also suggests phasing and scaling of first adaptation actions in a manner that allows both the Federal and NFS sufficient time to program the financial resources needed to execute subsequent adaptation action(s).



(Source: EP 1100 2-1)

Figure A-77: Impacts of Thresholds and Tipping Points on Future Decisions

As shown in **Figure A-77**, construction should be completed with a margin of safety before intervention is needed.

Based on the preliminary lead time analysis, the PDT is developing a recommended approach for the final report that would consider authorizing the first adaptation action and a range of possible subsequent adaptation action(s), subject to a RSLC monitoring. Additionally, the PDT is working to identify other triggers that would afford advanced investment for subsequent adaptation actions, which could reduce lead times by several years. Significant additional time savings can be realized if Congress authorizes and appropriates funding for design and entitlement of subsequent adaptation actions scaled to the High RSLC curve.

The regrets analysis will continue to examine the regret of over-investment and under-investment, with a primary focus on first and second actions in the TSP, to shape a final recommendation for consideration by decision-makers.

As the PDT continues to work on the regret analysis, the intent is to assess the following uncertainties and external factors that may influence an economically efficient adaptation pathway:

- The effect of different RSLC scenarios and the potential for over- or under-investment

- The spreading of investment in risk reduction over time to make it affordable to this and future generations
- An early action that precludes a preferable future action (such as raising the shoreline now and preventing a future retreat scenario)
- Coastal life safety risk if new coastal flood risk management adaptations are holding back the tide on a regular basis, where breach due to earthquake or overtopping might lead to risk to life, and options for reducing this risk through targeted retreat actions
- The opportunity to combine flood and seismic risk reduction that would lead to improved life safety and reduced earthquake damages
- The residual life of the assets along the shoreline and the potential loss of historic resources due to asset deterioration prior to a robust shoreline intervention
- Inability to adapt the first action to accommodate the actual rate of RSLC

A-11.5 Plan Refinement and Value Engineering After TSP

In alignment with USACE guidance on the Specific, Measurable, Attainable, Risk-Informed, and Timely Planning process, the PDT made necessarily broad assumptions across multiple disciplines to arrive at the TSP milestone. Schedule constraints have limited PDT capacity to analyze tradeoffs at the subarea geographic level and to develop phasing approaches. Throughout the process to reach TSP, the PDT has identified potential considerations for refinement post-TSP to further reduce coastal flood risk and seismic risk, reduce costs, reduce impacts, and gain additional community benefits based on professional best judgement.

It is standard practice within a feasibility study to consider such refinements post-Draft Report. Additionally, the PDT recognizes the value of documenting and reflecting such considerations in this Draft Report as a means of transparency for all reviewers. These potential refinements reflect considerations that were informed by public feedback on Alternatives A through G (which were shared with the public in October 2022) and early input from City staff and agency leaders, along with PDT professional best judgement.

The policy, planning, and value engineering considerations for refinement for the final report fall into four categories based on their intent: reduce multi-hazard risk, reduce impacts to communities and the Bay, increase historic resource benefits, and increase public access and ecological benefits.

A-11.5.1 Reduce Multi-Hazard Risk

After receipt of public and agency comments on this Draft Report, the PDT may consider potential opportunities to increase multi-hazard risk reduction (coastal flood risk and seismic impacts, including consideration of aging infrastructure beyond its design lifespan) by adjusting the phasing approach to install more robust coastal flood defense structures (actions currently described as TSP “subsequent actions,” which have moderately higher crest elevation, among other benefits) in targeted locations as the TSP 1st actions. Such refinement may be considered especially where near-term coastal flood risk is high along or adjacent to the current shoreline and existing coastal flood defenses. Example areas include portions of Fisherman’s Wharf and the southern edge of Pier 96.

In addition, this approach for TSP refinement may be considered where the more robust actions can be achieved at a comparable cost, which may include portions of Mission Bay shoreline and portions of the Islais Creek channel banks, pending further analysis.

The identification of targeted areas appropriate for more robust coastal flood defenses earlier in time is in line with the overall phasing approach, balancing the need for urgent risk reduction in some areas with a monitoring and adaptation which will be further defined post-TSP.

A-11.5.2 Reduce Impacts to Communities and the Bay

Further refinements to the TSP may include opportunities to reduce project impacts to communities and to the Bay. Based on professional judgement, opportunities to reduce impacts include 1) reduction or avoidance of new Bay fill (e.g., especially from the Bay Bridge through Mission Bay), and 2) reducing community disruption (primarily through phasing and implementation planning). Such refinements may also reduce costs and regulatory complexity, pending further analysis.

A-11.5.3 Increase Historic Resource Benefits

Further refinement of the TSP may include opportunities to increase risk reduction for and avoid impacts to key historic resources, including individual resources and components of group resources as listed in the National Register of Historic Places. One example could be to shift the alignment of the coastal flood defense structure to be adjacent to the bayside of the Ferry Building and Agriculture Building and replace the aging wharf substructure with a more robust basement structure (rather than on new raised wharves, as proposed in the current TSP), which would be designed in further detail during PED.

A-11.5.4 Increase Public Access and Ecological Benefits

Further refinement of the TSP may include opportunities to increase public access to the water and to open spaces, as well as opportunities for ecological benefits. In many cases, these measures may also contribute to coastal flood risk reduction (e.g., wave dissipation, erosion reduction) and the project’s mitigation strategy. Examples may include living seawall features, planted naturalized or embankment shorelines in lieu of gray structures where appropriate (e.g., along portions of Mission Bay), and targeted pockets of retreat where it may prove feasible (e.g., southwest bank of Islais Creek) if desired by adjacent communities for access to the water and open space.

A-11.5.5 Independent Measures for Consideration

The following list of “independent measures” represents a series of measures included in the NEPA analysis separately. Each measure was included (or was similar to a measure included) in one or more alternatives, but the given alternative as a whole was not proposed for inclusion in the TSP. These measures include:

- **Living Seawalls** (e.g., textured concrete on a vertical seawall) would be designed to reduce wave hazards while supporting nearshore ecology wherever current maritime uses and pier configurations allow. This measure was originally included in Alternative E (1st action) and is applicable to portions of Reaches 1, 2, and 3. Further detail available in Appendix I: Engineering with Nature
- **2A) Robust Coastal Defense of Ferry Building and Agriculture Building** would be designed to realign the coastal flood defense structure adjacent to the bayside edge of the Ferry Building and Agriculture Building. The structures could be raised in place with a basement structure or some solid fill underneath. This approach is anticipated to be preferable from a cost and engineering perspective. This is comparable to Alternative E (1st action) and may be considered in post-TSP refinement.
- **2B) Coarse Beach at Rincon Park** connecting to Pier 14 would be designed to reduce wave hazards, support nearshore ecology, and provide public water access. Some new Bay fill is included in this measure so as to address space constraints of the transportation network at this site. This measure is similar to the measure for this location included in Alternative F (1st action). Further detail available in Appendix I: Engineering with Nature
- **3A) Bay Bridge to South Beach Harbor Raised Shoreline with Rebuilt Wharves** from Bay Bridge to the mouth of Mission Creek, raise the current shoreline (rather than extending the shoreline into the Bay). This will require redesign of the northbound lanes of the Embarcadero roadway (in collaboration with SFMTA and the Embarcadero Enhancement Project), and the approach is intended to be designed to avoid reconstruction of the light rail track. This is comparable to Alternative G (2040) for this site.
- **3B) McCovey Cove North Curb Extension** raises the shoreline in line with the current shoreline edge on the north side of McCovey Cove (along the ballpark), rather than adding fill and extending the shoreline into the creek. This is comparable to Alternative G (1st action) for this site and may be considered in post-TSP refinement.
- **3C) Planted Naturalized or Embankment Shoreline on Mission Bay** south of Pier 50 would be designed to reduce wave hazards, support nearshore ecology, and provide public water access. This measure was originally included in alternative F (1st action) and may be considered in post-TSP refinement to

reduce impacts to the Bay, potentially reduce cost, and increase comprehensive benefits.

- **4A) Inland Coastal Flood Defense at Southwest Islais Creek** would include conversion of some industrial lands and public facilities to provide public water access, open space, and ecological benefits. It would also result in more permanent flood risk reduction due to a small area of gradual retreat along the creek. This is comparable to Alternative G (2nd action) between 3rd Street Bridge and the inland extent of the channel and may be considered in post-TSP refinement.

A-11.6 Plan Implementation

For the final report, the PDT will develop an implementation plan that considers the following key factors:

- Prioritization of investment in reaches, or sub-reach areas, based on coastal flood risk and seismic risk, including life safety risk
- Shoreline overtopping and flood measure outflanking risk
- Federal and local financial capacity
- Timing of major local investments more efficiently made in conjunction with the Recommended Plan (e.g., public-private partnerships to invest in piers, major roadway construction projects, bridge replacement projects)
- Cost effectiveness and efficient implementation
- Continued resident and visitor enjoyment of the waterfront and connection to the Bay
- Tenant access during construction when possible and tenant relocation when needed, recognizing proximity to the Bay for maritime and visitor-serving uses
- Availability of other major funding sources to implement the Recommended Plan

A-11.7 Plan Versus Strategy Over 100 Years

For the final report, the PDT will clarify the risk monitoring process to assess increase in risk over time in the study area to include specific elements such as a technical advisory panel, the process to track the following indicators to inform scaling and design of initial actions, and subsequent adaptations:

- Periodic updates to National Climate Assessments and State of California SLR guidance
- Rate of global warming

- Rate of ice sheet melting
- Water surface elevations

The governing process will build from comparable efforts in recent USACE efforts, such as the Breach Management plan defined for the Fire Island to Montauk Point General Reevaluation Report, which established specific process to reduce uncertainty in future actions as study area conditions vary over time.

The TSP recommends a specific Resilience Plan, which is a specific combination of structural and nonstructural measures to address anticipated flood risk within the study area over the POA. These measures are a subset of actions that are described within the larger resilience strategy for the area. The resilience strategy is a broader set of risk reduction features and scales that can be implemented to address flood risk at higher levels, which may be necessary sooner if a higher RSLC scenario is evident, or which may be implemented after the 100-year POA as flood risk increases. The resilience strategy is a longer-term concept that anticipates long-term needs and scales to support cost-effective, adaptable short-term actions, and the TSP is a Resilience Plan of actions described in the strategy.

Coordination among study area agencies will continue through TSP refinement and implementation. Coordination to date has informed plan development by confirming infrastructure maintenance and upgrade plans in the FWOP condition and managing potential FWP condition impacts that could result from alternative plans. The identification of a TSP will be an opportunity to begin coordination to align resources and long-term planning to define complementary resilience efforts across agencies.

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